GUAVA

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भाकृअनुप
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Preface

GUAVA is a hardy tree from tropical America. It produces fruits suitable for fresh consumption and processing. As an important fruit crop of India, it has gained considerable prominence on account of its high nutritive value, availability at moderate price, a pleasant aroma and good flavour. At present, it is grown throughout the country from sea level to 1,300 m altitude. Now, it is so much acclimatized that it appears to be native of India. Because of high calorific value, guava fruit has achieved fame as “poor man’s apple” in our country.

The research work on guava was started nearly hundred years ago in India. Improvement on guava for the first time was initiated during 1907 at Ganeshkhind Fruit Research Station, Pune, from where best guava Lucknow 49 or Sardar was released. Different state agricultural universities, research institutes and centres under All India Coordinated Research Project on Subtropical Fruits carried out enormous research on evolution or selection of cultivars, standardization of agro-techniques and post-harvest technologies. The need for a book on guava was felt in view of the lack of an up-to-date compilation of literatures on all aspects. The book will surely benifit the students, teachers, researchers, extension workers and growers.

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Kalyani

S.K. Mitra

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Contents

2

Origin, History and Distribution

CULTIVATED guava is a native to tropical America where it occurs wild (Purseglove, 1974) and it was domesticated more than 2,000 years ago (Cobley and Steele, 1976). It was reported to be common in many parts of West Indies and the improved forms were planted by the local inhabitants (Purseglove, 1974). It was spread at an early date throughout the world's tropics by the Spanish and Portuguese (Purseglove, 1974; Cobley and Steele, 1976). The wide adaptability nature of guava tree helped it to sustain wide range of environments and soils. It has been naturalized in many countries and in some places it has spread so extensively as to become a weed, for, e.g in Fiji (Purseglove, 1974; Cobley and Steele, 1976). It is grown in Sri Lanka from sea-level to an altitude of 1,515 m and throughout Myanmar. Presently, guava is cultivated commercially in South Asian countries, the Hawaiian islands, Cuba and India.

It is believed to have been introduced in India at a very early date, as it was mentioned by Bruton who was in India early in the 17th century (Hayes, 1974). Though it is grown successfully throughout the country, the most important guava-producing states are Uttar Pradesh, Bihar, Madhya Pradesh and Maharashtra. Uttar Pradesh is by far the most important guava-growing state in India and Allahabad has earned the reputation of producing the best guava in the country as well as in the world (Mitra and Bose, 1990).

3

Area and Production

GUAVA is the fourth most important fruit in India after mango, banana and citrus. In India, it is mainly grown in Bihar, Uttar Pradesh, Karnataka, Madhya Pradesh, Gujarat, Andhra Pradesh and Maharashtra. In 1950, only 52.4 thousand ha was under guava cultivation which increased to 131.6 thousand ha in 1995–96 (Table 1).

Table 1. State-wise area, production and productivity of guava in 1999–2000

State	Area ('000 ha)	Production ('000 tonnes)	Productivity (tonnes/ha)
Andhra Pradesh	10.7	127.9	12.0
Bihar	31.5	378.0	12.0
Gujarat	6.3	90.8	14.4
Karnataka	12.6	157.7	12.5
Madhya Pradesh	7.1	142.6	20.1
Maharashtra	17.6	211.4	12.0
Orissa	12.0	52.5	4.4
Punjab	3.4	59.8	17.4
Tamil Nadu	9.2	84.9	9.2
Uttar Pradesh (plains)	18.0	185.0	10.3
Others	20.0	219.8	–
Total	150.9	1,710.5	11.3

Source: Department of Agriculture and Cooperation, 1998. Indian Horticulture Database (National Horticulture Board), Ministry of Agriculture, Government of India.

The production increased from 238.2 thousand tonnes to 1,501.3 thousand tonnes in the same period. The productivity of 4.55 tonnes/ha in 1950 increased to 11.41 tonnes/ha in 1995–96. The highest productivity (25.24 tonnes/ha) was in Uttaranchal, while highest area is in Bihar (27,296 ha), followed by Uttar Pradesh (plains) and Karnataka.

4

Species, Cultivars and Varietal Improvement

SPECIES

GENUS *Psidium* belongs to family Myrtaceae and contains about 150 species (Hayes, 1974), of which most widely cultivated is common guava, *P. guajava* (Purseglove, 1974). The Brazilian or Guinea guava, *P. guineense* sw. bears small fruits with poor quality. The common guava, *P. guajava* var. *aromaticum* yields small-sized fruits, while fruits of *P. pomiferum* are round and that of *P. pyriferum* pear-shaped (Mitra and Bose, 1990). The *P. guajava* var. lucidum Degener has yellow fruits (Purseglove, 1974). The mountain guava, *P. montanum* sw, which grows wild in the Jamaica hills, is a shrub of about 1.5 m height with flat and round branchlets. The Chinese guava, *P. friedrichsthalianum* (Berg.) Nied. is a native of central America (Purseglove, 1974) and bears small and globose fruits with high acid content (Purseglove, 1974; Mitra and Bose, 1990). *P. microphyllum* Britton is grown in Puerto Rico (Purseglove, 1974). The strawberry guava (*P. cattleianum* Sabine), a native of Brazil (Purseglove, 1974), is a relatively hardy subtropical species closely related to the guava, with round, red fruits about 2.5 cm in diameter (Normand, 1994). The common guava was formerly classified as *P. pyriferum* and *P. pomiferum* based on their shapes.

Besides, *P. acutangulum*, *P. firmum* (wild species), *P. araca*, *P. littorale*, *P. molle* and *P. coriaceum* are growing in different countries (Mitra and Bose, 1990).

The guava is a shallow-rooted shrub or small tree spreading up to 3–10 m in height having branches close to the trunk with smooth, greenish or reddish brown or multi-coloured bark peeling anually in thin flakes (Purseglove, 1974). The newly-emerged shoots are square in cross section and pubescent. Simple leaves are opposite, oval almost sessile and light green in colour. Veins are prominent on soft under surface and markedly depressed on upper surface. Ray *et al.* (1993) observed maximum feeder root density at the mid point (from tree trunk) than at drip line. The density and activity of feeder roots decrease with an increase in distance from 120 cm to 360 cm from tree trunk (Purohit and Mukherjee, 1974).

Attractive white flowers are borne axillary, about 2–3 cm in diameter, solitary or in cymes of 2–3 flowers; calyx entire in bud, splitting irregularly into 4–6 lobes, 1–1.5 cm long, reflexed, pubescent, persistent; petals 4–5, white, obovate concave, reflexed, 1–2 cm long; stamens numerous, inserted in rows on disc, 1–2 cm long, filaments white, anthers pale yellow dehiscing lognitudinally; ovary 4–5 locular; style fliliform, greenish yellow 1.5–2 cm long, exerted above stamens; stigma capitate (Purseglove, 1974). After fertilization the ovary develops into a globular or pear-shaped berry up to 10 cm long and 5 cm or more in diameter. The small yellowish seeds are embedded in white or pink flesh of mesocarp which normally contains sclerides, i.e. stone cells (Cobley and Steele, 1976).

Following species are available at various research stations in India (Yadav, 1990).

***Psidium* species**	**Research stations**
P. acutangulum	IIHR, Bangalore
P. araca	Horticulture Experiment and Training Centre (HETC),Basti
P. araca Florida	HETC, Saharanpur
P. cattleianum	HETC, Basti; NDUAT, Faizabad
P. chinensis	HETC, Basti; NDUAT, Faizabad
P. cujavillis	HETC, Basti; NDUAT, Faizabad
P. friedrichsthalianum	HETC, Basti; NDUAT, Faizabad
P. guineense	HETC, Basti, NDUAT, Faizabad
P. montanum	IIHR, Bangalore
P. pumilum	HETC, Basti; HETC, Sharanpur

CULTIVARS

The nomenclature of different cultivars (clonal) of guava grown in India is yet to be established. Some cultivars were named according to their shapes (Karela), colour (Apple Colour, Chittidar, Red-Fleshed), and smoothness of skin, while others like Allahabad Safeda, Banarasi, Barmpur, Harijha, Nasik, Sindh etc.were named after their places of origin (Mitra and Bose, 1990; Pathak and Ojha, 1993). The cultivars of Andhra Pradesh, Assam, Bihar, northern Madhya Pradesh, Mumbai, north-eastern region, Uttar Pradesh and West Bengal were described by Ibrahim (1943); Dutta (1953); Kumar (1998); Tripathi *et al.* (1971); Cheema and Deshmukh (1927); Chandra and Govind (1991); Teaotia *et al.* (1969); Mitra *et al.* (1983) and Kundu *et al.* (1995) respectively.

A number of non-descript cultivars were found to grow in Assam and named according to locality and language such as Madhuri-Am (Assam valley plains), Safri or Payere (Cachar), Soh-Priya and Am-Sophri in Khasi Hills and Garo Hills, respectively (presently in Meghalaya) (Dutta,

1953). Non-descript seedling guavas are found to grow sporadically throughout North-eastern region of India (Chandra and Govind, 1991) and their potential in this region was evaluated by Gurung and Singh (1980). Chandra and Govind (1991) recommended that Lucknow 49, Allahabad Safeda and Red Fleshed with better yield, quality and precocity can be adapted on commercial scale in lower midhills of North-eastern region.

Teaotia *et al.* (1969), reported that out of Chittidar, Lucknow 42, Allahabad Safeda, Seedless, Red Fleshed, Lucknow 49 and Karela Lucknow 42 was most suitable for canning and Allahabad Safeda for cultivation in dry tract. Lucknow 49 produced fruits of excellent quality with geater fruit size, and lesser number of seeds per fruit than that of Chittidar and Safeda (Sehgal and Singh, 1965). Srivastava and Srivastava (1965) opined that fruits of Allahabad Safeda were high in brix, acidity, ascorbic acid and sugar contents, whereas Red Fleshed was rich in starch, crude fibre and tannin.

Guava Chittidar and Safeda showed some characteristic features. Chittidar could be easily distinguished by the presence of red dots on fruits (Sehgal and Singh, 1965; Mitra, 1983). Safeda also had few red dots with globose in shape and small in size. The results of the comparative evaluation of different cultivars revealed that Lucknow 49, renamed as Sardar, was the best among the cultivars (Chandra and Govind, 1991; Mitra, 1983). Pandey *et al.* (1997) in an evaluaion trial with 9 cultivars observed that Seedless produced tallest tree but had lowest yield and net profit. Chittidar had a spreading habit and showed maximum volume and yield. Gwalior 27 and Apple Colour were dwarf cultivars. Allahabad Safeda and Sardar had best quality fruits with good organoleptic traits. Sardar has been identified as most promising cultivar of India due its wide adaptibility, high yield with good quality fruits (Chandra and Govind, 1991). On the basis of overall performence, Lucknow 49 has been found to be best-suited for commerical plantation in semi-arid lateritic belt of West Bengal, although Chittidar and Allahabad Safeda may also be considered (Ghosh and Chattopadhayay, 1996).

The term red-fleshed covers various shades of pink fruits. Teaotia *et al.* (1969) reported that Ankapalle, Red Fleshed, Super Acid, Florida Seedling, Hybrid Red Supreme, Africa, Florida, Portugal, China Surkha, Kothrud, Patillo and Allahabad were among red-fleshed cultivars. Red Fleshed, grown in Barapani, Shillong at 1,000 m above mean sea-level showed maximum plant height, stem girth, fruit size and yield but fruit quality (particularly vitamin C and sugar content) were inferior to Lucknow 49 and Allahabad Safeda (Chandra and Govind, 1991).

Guava Seedless though produced good quality fruits with few seeds, the bearing is very poor with small fruit size. It was, therefore, not

considered as a cultivar of commerical importance (Sehgal and Singh, 1965).

In Porto Lucena, Brazil, Riverside Vermelha is recommended for the physical characteristis of fruits, while IAC 4, and clones RBS 1 and RBS 2 are recommended for fresh consumption and processing (Gerhardt *et al.* 1997). The suitability of guava hybrids for preparation of nectar, a procesed juice product, was evaluated by Baramanray *et al.* (1995) and it was found that hybrids 3-22, 12–34 and 5–27 were suitable for preparation of nectar. In Bihar, under rainfed condition, maximum fruit weight, TSS, ascorbic acid, reducing sugar and TSS : acid ratio were recorded in Selection 8, followed by Apple Colour, Sardar, Red Fleshed and Allahabad Safeda, whereas pectin content was maximum in Allahabad Safeda followed by Selection 8 and Red Fleshed (Kumar, 1998).

A seedling selection, CISH G 1, has been reported to be very promising. Its fruits are deep red in colour having soft and few seeds with high yield potential and good quality (Negi, 1996). The promising cultivars suitable for growing in different states of India are given in Table 2.

Table 2. Cultivars suitable for growing in different states of India*

State	Cultivars
Andhra Pradesh	Allahabad Safeda, Anakapalli, Banarasi, Chittidar, Hafsi (Red Fleshed), Lucknow 46, Sardar, Smooth Green, Smooth White
Assam	Am-Sophri, Madhuri-am, Safrior Payere
Bihar	Allahabad Safeda, Apple Colour, Chittidar, Hafsi (Red Fleshed), Harijha, Sardar, Selection 8
Maharashtra and Gujarat	Dharwar, Dholka, Kothrud, Lucknow 24, Lucknow 49, Nasik, Sindh
North-eastern States	Allahabad Safeda, Sardar, Red Fleshed
Tamil Nadu	Anakapalli, Banarasi, Bangalore, Chittidar, Hafsi (Red Fleshed), Nagpur Seedless, Smooth-Green
Uttar Pradesh	Allahabad Safeda, Apple Colour, Chittidar, Red Fleshed, Banarasi Surkha, Sardar, Mirzapuri Seedless.
West Bengal	Allahabad Safeda, Baruipur, Chittidar, Harijha, Sardar

**Source:* Chandra and Govind (1991), Ghosh and Chattopadhyay (1996), Kumar (1998), Mitra (1983), Pathak and Ojha (1993)

Nakasone *et al.* (1976) stated that Beaumont was first processing cultivar introduced to the Hawaii industry and was the only recommended

processing guava until the introduction of a selection Kahua Kula in 1976. The fruits of Beaumont are large (average weight 170 g) with 7–10% TSS content and 1–1.25% titratable acidity. The physico-chemical characteristics of fruits of Kahua Kula was somewhat similar to that of Beaumont with a slighlty stronger pink colour and slightly higher acidity (Nakasone and Paull, 1998). Both the cultivars are heavy yielders, exceeding 227 kg/tree/year after the fifth year with some pruning.

Malherbe and Fan Retief with mild sweet taste and light pink colour are recommended as dessert types, though they can be used for canning as halved fruit. As processing types, Beaumont, Kahua Kula and Waiakea are recommended for Hawaii (Nakasone and Paull, 1998).

A number of cultivars, dessert as well as processing types, have been developed in Florida. The fruits of Ruby, Supreme and Ruby × Supreme are considered to be excellent for dessert purpose. One hybrid, Homestead (6–29), was released in the early 1960's. Pink Acid and Patillo are two acid cultivars (total acidity 1.7%) with dark pink colour, suitable for processing (Malo and Campbell, 1986). In south eastern Queensland, clone GA 11-56 was recommended of commercial planting (Chapman *et al.*, 1981).

Characteristics of important guava cultivars grown in India are:

Allahabad Safeda

Allahabad Safeda

This is most popular among growers of Uttar Pradesh. Trees are vigours, upright, tall, with medium to heavy branching, having a tendency to produce long shoots. Crown broad and compact. Leaves are long and

wide, elliptical to oblong in shape. Fruits are medium to large (average weight 150–200 g), round, smooth with yellowish skin at maturity. Fruits are soft when ripe with pleasant flavour and good keeping quality. The TSS, acidity and ascorbic acid contents are 12.6 and 0.41%, and 172 mg/100 g pulp (Daulta *et al.*, 1998).

Anakapalle

Fruits are medium-sized with red pulp. Seeds are soft and in plenty. Skin pinkish yellow with small red dots. Keeping quality is good.

Apple Colour

Apple Colour

This cultivar has been originated from Allahabad district. Even though it is not a heavy bearer, this cultivar is grown because of its attractive colour and good quality fruits. Trees are medium in height with broad crown and spreading growth. Fruits are 80–120 g in weight, spherical in shape, dawn-pink in colour with deep minute dots on the surface. The TSS, acidity, ascorbic acid and pectin contetns are about 11.0 and 0.17%, and 209 mg/100 g pulp and 0.59%, respectively (Kumar, 1998).

Banarasi Surkha

Trees are medium to tall with broad crown (Daulta *et al.*, 1998). Leaves are long, oblong in shape with acute apex and obtuse base. Fruits are round with smooth surface, golden yellow skin and pink flesh colour. Fruits are 70–80 g in weight with many hard seeds. The TSS, acidity and

ascorbic acid contents are 9.1 and 0.48%, and 149 mg/100 g pulp, respectively (Daulta *et al.*, 1998).

Baruipur

This is one of the important commercial cultivars of West Bengal. Trees are medium to tall having spreading growth habit with broad and compact crown. Leaves are long, broad and oblong in shape. Fruits are round, dresden-yellow in colour with white flesh and moderate keeping quality.

Behat Coconut

This cultivar has been originated from village Behat in Saharanpur (Uttar Pradesh) (Chandra and Chandra, 1997). Trees are tall, moderately vigorous with flat crown and heavy branching habit, having dark brown coloured bark. Leaves are large, ovate lanceolate in shape and sometimes twisted. Fruits are medium to large, oval to round in shape with aureoline coloured skin. Fruit surface is smooth with dots, flesh is white and sweet. Fruits are sweet in taste with good keeping quality.

Chittidar

Trees are tall with rounded crown, spreading branches and moderate bearing habit. Leaves are long, elliptic-oval to oblong-elliptic in shape with acute apex and round base. Fruits are small to medium, subglobose in shape, straw-yellow in colour with red spots of pin-head size on fruit skin. The TSS, acidity, ascorbic acid and pectin contents are about 10.1 and 0.18%, and 196 mg/100 g pulp and 0.51%, respectively (Kumar, 1998).

Dholka

It is a popular cultivar of western India. Fruits are medium to large with good quality.

Hafsi

This is native to Bihar. Fruits are spherical, medium in weight with thin skin and creamy white soft pulp having distinct pleasant flavour. Fruits with red flesh are not as sweet as white fleshed ones. Fruits contain vitamin C of 240 mg/100 g pulp (Subramanyam and Iyer, 1993).

Harijha

Trees are medium in size, sparsely branched with profuse bearing habit. Leaves are medium in size, lanceolate, apex acute and base round.

Round fruits are greenish yellow in colour and sweet in taste with good keeping quality.

Karela

Fruits are pear-shaped with rough skin. Pulp is whitish with sweet taste.

Lucknow 46

Fruits are large, pyriform in shape. Flesh is whtie in colour with good flavour and contains 128 mg/100 g pulp and vitamin C (Subramanyam and Iyer, 1993).

L49

Lucknow 49

Popularly known as Sardar, it has been evolved through selection made at Poona (Cheema and Deshmukh, 1927). Trees are semi-dwarf, vigorous, heavy branching type with flat crown. Leaves are large, long, elliptic-ovate to oblong in shape. Fruits are spherical to round in shape with primerose-yellow skin colour having red dots on the skin. Pulp is white with many seeds. The TSS, acidity and vitamin C contents are 11.16 and 0.42%, and 149.9 mg /100 g pulp, respectively (Chandra and Govind, 1991).

Nasik

It is a popular cultivar of Maharashtra and Gujarat. Fruits are bottle-

shaped having rough skin with good keeping quality.

Navalur

This variety is grown in Dharwad region of Karnataka. It is hardy in nature, drought tolerant and resistant to canker.

Pear Shaped

This cultivar was originated from Uttar Pradesh. Trees are tall and upright with medium branching habit. Leaves are medium in size, elliptical in shape, coarse and leathery. Fruits are pyriform, attractive with straw yellow coloured skin. Surface is smooth with large dots. Storage life is good.

Red Fleshed

Vigorous and tall tree with spreading branches and open vase form crown. Leaves are mediun in size, elliptic-oblong in shape. Fruits are roundish-ovate in shape, medium-sized, dawn pink flesh and smooth skin having few red dots on surface. Keeping quality is poor to medium.

Seedless

Trees are tall with relatively long trunk and upright branches. Leaves are large and oblong in shape. Fruits are medium in size, irregular in shape with straw-yellow skin. Pulp is white in colour with few or very less seeds, contains 83–168 mg/100 g pulp ascorbic acid. Keeping quality is excellent.

Selection 8

Trees are medium to large with moderate yield. Fruits are large with soft seeds. The TSS, acidity, ascorbic acid and pectin contents are 11.0 and 0.17%, 210 mg/100 g pulp and 0.69%, respectivley (Kumar, 1998).

HYBRIDS

Arka Amulya

It is a hybrid of Allahabad Safeda and Triploid. Plants are semi-vigorous and spreading. Fruits are medium-sized, white flesh, TSS is high (12.5^{0}Brix) with good keeping quality.

Safed Jam

This is a hybrid of Allahabad Safeda × Kohir (a local collection from Hyderabad-Karnataka region) developed at Fruit Research Station (FRS),

Arka Amulya

Sangareddy, Andhra Pradesh. Fruits are big with few soft seeds and good keeping quality. The ascorbic acid content is higher than both the parents.

Kohir Safeda

It has been evolved by crossing between Kohir and Allahabad Safeda and released from FRS, Sangareddy, Andhra Pradesh. Fruits are large with few, soft seeds and white coloured pulp. Yield and fruit quality are better than the parents.

Hybrid 1

This has been originated from the crossing between Seedless and Allahabad Safeda at IIHR, Bangalore. Trees are semi-vigorous and heavy yielder. Fruits are medium with few soft seeds. Pulp is white with good quality and storage life (Subramanyam and Iyer, 1993).

Hybrid 16-1

A hybrid of Apple colour and Allahabad Safeda developed at IIHR, Bangalore. Trees are semi-vigorous with moderate yielding capacity. Fruit skin is bright red in colour. Flesh is firm with few seeds and good keeping quality (Subramanyam and Iyer, 1993).

H 21

It is a hybrid between Red Flesh × Arka Mridula. Plants are erect. Fruits are round to oval in shape with red colour pulp. Seeds are medium soft and few in number. TSS is high (12.5°Brix). Keeping quality is good.

Hisar Safeda (H 25-25)

This is a hybrid of Allahabad Safeda × Seedless. The tree has upright growth with a compact crown, fruits are round, about 92 g in weight, with creamy white pulp and few, soft seeds. The TSS and ascorbic acid contents are 13.4% and 185 mg/100 g pulp, respectively (Daulta *et al.*, 1998).

Hisar Surkha (H 12-34)

It is a hybrid of Apple Colour and Banarashi Surkha. Tree is medium with broad to compact crown. Round fruits weigh about 80 g each. Pulp is pink having 13.6% TSS, 0.48% acidity and 169 mg/100 g pulp of ascorbic acid (Daulta *et al.*, 1998).

The physico-chemical composition of some guava cutlivars are given in Table 3.

Table 3. Physico-chemical characters of guava cultivars*

Cultivar	Average fruit weight (g)	Total soluble solids (°Brix)	Total sugar (%)	Ascorbic acid (mg/100 g of pulp)
Allahabad Safeda	90–160	8.4–10.6	6.8–8.5	110–192
Apple Colour	80–120	7.8–11.6	6.2–7.3	115–230
Banarasi	90–130	9.2–10.3	6.8–8.0	78–190
Baruipur	88–125	8.8–9.3	6.8–7.6	105–180
Behat Coconut	82–156	9.0–9.4	6.8–7.7	88–168
Chittidar	95–152	8.2–10.6	6.4–8.8	97–234
Harijha	82–135	8.6–9.2	6.3–7.9	92–165
Kerala	76–117	9.1–9.8	6.6–8.4	84–185
Pear Shaped	79–131	8.8–9.6	6.7–7.5	75–157
Red Fleshed	92–135	8.2–11.0	7.0–10.4	75–226
Sardar	96–188	9.2–11.6	7.3–10.6	133–216
Seedless	71–87	8.4–9.2	6.7–7.4	83–168

*Mitra *et al.* (1983), Kundu *et al.* (1995), Ghosh and Chattopadhyay (1996), Daulta *et al.* (1998), Kumar (1998), Reddy *et al.* (1999).

VARIETAL IMPROVEMENT

In guava, most of the commercial cultivars are diploid (2n = 22) in nature (Kumar, 1973), while seedless cultivar is reported to be triploid (2n=33) in nature (Raman *et al.*, 1971). The chromosome number of *P.*

friedrichsthalianum is 2n = 22 (Srivastava, 1977).

The primary objectives of guava breeding are to develop resistant, high-yielding varieties with good fruit quality. Other considerations are long shelf-life, attractive appearance, seedlessness and soft seededness, texture and processing quality. Nakasone and Paull (1998) recommended a set of selection criteria in a breeding programme that should include all or some of the followings.

Selection criteria

- Vigorous, spreading, low growth type
- Resistant to tree diseases and pests
- High yield
- Dwarfing rootstock
- Large (200–340 g), fruits with few seeds and thick pulp
- White for dessert or dark pink pulp colour for processing
- Flavour and aroma characteristics of fresh guava, with no woody off flavour or muskiness
- More than 10% total soluble solids
- For processing, an acidity of 1.25–1.50% and, for dessert guava, 0.2–0.6%
- Vitamin C content of 300 g/kg or higher
- Minimum number of stone cells
- Good post-harvest shelf-life
- Resistance to fruit diseases and insects.

Attempts were made to breed cultivar with less seeds and higher productivity by crossing between triploid and diploid at IARI, New Delhi (Majumder and Mukherjee, 1972 a,b). Out of 73 progeny plants raised, 25 were found diploid, 9 trisomic and 5 terasomic (2n + 1+ 1). The fruits of tetrasomics were normal is shape, size and with less number of seeds. In recent years, aneuploidy breeding has been paid some atention. The chromosome imbalance thus obtained in aneuploid, imparts certain amount of ovular sterility, which in turn results in reduced seed formation and size. In 1962, De'Cruz and Babu Rao isolated two aneuploids, one with 21 and the other with 30 chromosomes from a progeny of triploid guava. The trisomic, in general, produces smaller fruits with fewer seeds in comparison to diploid cultivars. The fruits of tetrasomic plants are smaller with fewer seeds than the trisomics. Some of the tetrasomics are extremely dwarf and can be used as dwarfing rootstock. Natural autotetraploid has been reported in the genus *Psidium* (Nithani and Srivastava, 1966) and tetraploidy could be induced in Allahabad Safeda by treating the shoot tips with 0.1% aqueous solution of colchicine (Kumar, 1973). Iyer and Subramanyam (1971) opined that production of more triploids was futile as the fruit shape in triploids is highly irregular. A potentially dwarf

aneuploid No. 82 has been identified at IARI, New Delhi (Sharma, 1982).

Efforts have been made to estimate the heritability pattern in guava. Some important triats like yield, fruit size, fruit quality (ascorbic acid, acidity, pectin etc.) and disease resistance have been found to be in low heritability category and not determined solely by major genes although basic genes, subject to the modifying effects of polygenes, have been identified for some quality traits like skin colour and acidity (Ray, 1999). In guava, red pulp colour and bold seeds were reported to be dominant over white colour and soft seeds respectively, and a linkage could be formed between red flesh colour and bold seed size (Subramanyam and Iyer, 1982). Obovoid shape of fruit is dominant over round and pyriform (Ray, 1999). Raman *et al.* (1971) suggested that hybridization among less seeded diploids, selection of good improved strains through surveys and development of autotetraploid from superior less seeded fruits could be the possible lines for improvement. The cross incompatibility between several varieties, e.g. Lucknow 49, Apple Colour and Behat Coconut has been reported (Chadha, 1998).

Selection

The natural self-pollination in guava with 35% outcrossing results in a heterozygous, open-pollinated seedling population, with adequate genetic variation for selection of desireable commercial types (Nakasone and Paull, 1998). Selection can also be made from wild population. Guava improvement work was initiated long back in 1907 at Ganeshkhind Fruit Experimental Station, Pune (Phandis, 1970). Seeds were collected from various guava-growing belts and seedlings were evaluated to identify superior types for fruit and yield characters (Cheema and Deshmukh, 1927). One strain from open-pollinated seedlings of Allahabad Safeda collected from Lucknow was identified and released as Lucknow 49, which became very popular for its high yield with good quality fruits; which later renamed as 'Sardar' and recommended for commercial cultivation (Singh, 1953). Experimental results corroborate that this variety is suitable for growing almost throughout the India. At NDUAT, Faizabad, out of 23 strains collected from survey, 3 seedlings of Allahabad Safeda (AS_1, AS_2 and AS_3) and 2 seedlings of Faizabad selection (FS_1 and FS_2) were reported to be promising in yield and fruit quality (Pathak and Dwivedi, 1988).

Sixteen high performing seedlings were selected from variety Navalur in Kanataka, which were hardy, drought tolerant and canker resistant (Hulamani *et al.*, 1981). Arka Mridula (Selection 8) is a selection from 200 open-pollinated seedlings of variety Allahabad Safeda, which appears to be promising for its dwarf nature, high yield with medium-sized fruits having white pulp and few soft seeds. The fruit quality and shelf- life are

good (Iyer and Subramanyam, 1988). Recently a seedling selection, CISH-G1, has been identified as very promising at Central Institute for Subtropical Horticulture, Lucknow, because of high-yielding potential and good quality. The fruits are deep red in colour with few soft seeds (Negi, 1996). In Maharashtra, 12 strains have been collected from Aurangabad and Bhir districts. Of them, ABD3, BHR3 and BHR5 were found superior (Thonte and Chakarwar, 1981).

Hybridization

Attempts have been made to evolve hybrids with desireable traits at various research stations in India and some promising results have emanated from the systematic approach to produce F_1 hybrids. At IIHR, Bangalore, Hybrid 1 and Hybrid 16-1 have been reported to be promising (Subramanyam and Iyer, 1993). Safed Jam and Kohir Safeda are hybrids developed at Fruit Research Station, Sangareddy, Andhra Pradesh. From a number of crosses by using Allahabad Safeda, Seedless, Apple Colour, Lucknow 49, Red Fleshed and Banarasi Surkha as parents. Two new guava hybrids Hisar Safeda and Hisar Surkha were developed from CCS Haryana Agricultural University, Hisar (Daulta *et al.*, 1998).

5

Soil and Climate

SOIL

GUAVA trees are adaptable to a wide range of soils from light sandy loam to clay soils. They can be grown on heavy soil with proper drainage facility. It thrives on shallow, infertile soil, although growth and production are poor. The ideal soil for guava is, however, deep, well-drained, friable, fertile loamy soil. The trees are fairly resistant to salt and drought and may grow on a wide range of pH from 4.5 to 8.2. Although its cultivation in soil with a pH less than 5 or higher than 7 has also been observed. Guava is reported to be very (Ogden *et al.*, 1981) to moderately (Schaffer *et al.*, 1992) flood tolerant and can thrive on poorly drained land where most other fruit trees do not grow (Morton, 1987). They can tolerate temporary waterlogging (Purseglove, 1974). Most of the feeder roots remain concentrated within 20 cm of top soil, so top soil should be fertile.

Experimental evidence suggest that it is fairly tolerant to soil salinity (Malo and Campbell, 1986). Varying degrees of susceptibility of different cultivars to soil salinity have been reported. Guava Sardar has comparatively better field tolerance to wilt and sodicity compared to Allahabad Safeda (NDUAT, 1991). It bears successfully up to an electrical conductivity of soil saturation extract of 8–9 dS/m (Mehta *et al.*, 1988). However, Patil *et al.* (1984) reported a threshold ECe of 4.7 dS/m and a decrease in growth of almost 10% per dS/m above this threshold. Increasing salinity level (EC values from 4.5 to 12 mmhos/cm) caused a decrease in total N, P, K and Na concentraions in dried leaves and total chlorophyll content in guava seedling in Sardar, while Ca, Mg and Cl showed an opposite trend (Singh and Pathak, 1994). Substantial rise in Na and Cl content of leaves was noticed with increasing salinity (Makhija *et al.*, 1980; Dhankar *et al.*, 1981; Haggag and Maksoud, 1996) resulting into leaf injury and reduced shoot growth, which might be attributed to Na and Cl toxicity and the imbalance of other nutrients at higher levels of salinity (Marler, 1994). Seed germination and seedling emergence have

been reported to be delayed at all levels of salinity (Maas, 1984). It seems that crop is more sensitive to salinity stress during germination and emergence than during later growth (Marler, 1994). Haggag and Maksoud (1996) reported that fruit weight, size and ascorbic acid content decreased significantly at higher salinity level.

CLIMATE

Guava performs equally in tropical as well as in subtropical regions. Its trees are quite hardy and adaptable to a wide range of climatic condition and environmental stresses (Marler, 1994). It does best in warm areas with abundant moisture (Maggs, 1984). It can be grown up to an altitude of 1500 m provided the region is frost free, as it susceptible to frost (Purseglove, 1974).

The optimum temperature is 23–28°C (Samson, 1980). In areas having distinct winter season, the yield tends to increase and quality improves. A temperature lower than 23°C and higher than 27°C during flowering reduces fruit setting. At higher elevations of Hawaii, flower abortion occurs when winter temperature goes as low as 7°C (Shigeura and Bullock, 1983). Young plants are reported to be killed at –2°C, if it continues for a long time (Malo and Campbell, 1986). However, Cattley guava is reported to be able to survive at a temperature below –5°C (Morton, 1987). The growth of tree ceases and leaves become purple in region where winter night temperatures are 5–7°C for few hours (Nakasone and Paull, 1998). High temperature coupled with low humidity during summer season reduces fruit setting and augments fruit drop (Chadha and Pandey, 1986).

Mature guava tree is fairly tolerant to drought (Ogden *et al.*, 1981). However, young plants are susceptible to drought and cold conditions. Optimum annual rainfall varies from 100 to 200 cm (Samson, 1980). The ideal rainfall pattern for guava is alternating dry and wet spells. Low moisture condition particularly during fruit growth period reduces fruit size.

Guava appears to be insensitive to photoperiod. Light saturation for guava leaves (a C_3 plant) is in general, high and above 925 mmol/m^2/second photosynthetic photon flux (Walkar *et al.*, 1979; Nakasone and Paull, 1998).

Guava trees are hardy and tolerant to strong wind, though defoliation occurs to some extent. Shigeura and Bullock (1983) reported that growth is sensitive to wind loads. Young trees (up to 3 years) raised from rooted cuttings are subjected to uprooting by winds at 65–80 km/hr which might be due to faster top growth than root growth (Nakasone and Paull, 1998). It, therefore, appears that windbreaks are essential for obtaining better quality dessert guavas.

6

PROPAGATION

GUAVA can be propagated very easily by seeds (Mukhopadhyay and Sen, 1986). However, seed propagation should be avoided as owing to heterozygous nature of tree and cross-pollination, the seedling raised plants are never true-to-type. Apart from a longer juvenile phase the seedlings differ widely in yield and physico-chemical characteristics of fruits. Seedlings, however, are used as rootstocks. Several methods of vegetative propagation techniques have been standardized in guava.

SEED PROPAGATION

The seedlings can be raised in nursey or in polyethylene bags. Though guava seeds retain their viability for a considerable period, it is better to sow seeds immediately after extraction from fruits. The viability of seeds can be extended if they are washed, dried and stored in an air-tight container in a dry cool place (Cheema *et al.*, 1954). About 50% viability of seeds could be maintained up to 18 months when they were stored, with or without charcoal in sealed tin container or in glass or polyethylene jar (Chacko and Singh, 1968). Seeds could be stored for 104 days, when they were pre-soaked in ferulic acid at 10^{-3}M concentration (Mitra and Bose, 1990).

The seed coat of guava is quite hard and causes delay in germination. Acid scarification and boiling in hot water for 5 minutes of seeds shortened the time required for germination without any adverse effect on germination percentage (Hayes, 1974). A combination of scarification in sand for 15 minutes and germination in sand gave the best total germination (98.15%) and seeds germinated 8 and 11 days after sowing (Tavares *et al.*, 1995). Soaking of seeds in 500 ppm ethephon followed by in NAA (Sinha *et al.*, 1973) or in GA_3 (3000 ppm) solutions (Chandra and Govind, 1990) caused marked increase in percentage of germination and seedling growth. Singh and Soni (1974) reported that soaking of seeds of Allahabad Safeda and Red Fleshed in water for 12 hours or in hydrochloric acid for 3 minutes gave 90% germination in comparison with 58% in the control. Pandey and Singh (2000) noted 90% germination of seeds of Allahabad

Safeda by soaking in water for 36 hours before sowing.

In northern India, seeds fail to germinate satisfactorily if sown during November to June, and so sowing of seeds in rainy season is recommended (Singh and Singh, 1988). Normally, seeds of winter crop are collected (Singh *et al.*, 1963) and sown with the onset of monsoon (Sinha *et al.* 1973). One-year-old seedlings are used as rootstock for grafting and budding.

VEGETATIVE PROPAGATION

Cuttings

Although guava is a difficult-to-root plant, but it can be propagated clonally by stem cutting under mist (Mitra and Bose, 1990). Teaotia and Pandey (1961) observed that both NAA and IAA at 50 and 100 ppm, encouraged rooting of semi-hardwood etiolated cuttings. Different types of auxins were used in rooting of guava cuttings. About 65% rooting was obtained in Seedless guava by dipping the basal ends of 1.0–1.25 cm thick and 20 cm long cuttings with 6-8 buds in 100 ppm NAA for 12 hours, while IBA treatment gave only 40% success. Sen *et al.* (1969) obtained 100% rooting was observed in leafy cuttings of guava under intermittent mist by treatment with IBA. Two-node cuttings of guava Paluma, taken from shoots with fruits, rooted best under intermittent mist when treated with IBA at 200 ppm for 14 hours in darkness (Pereira *et al.*, 1991).

Maturity of shoots have been reported to have strong bearing on rooting success of guava stem cuttings. Bhandari and Mukherjee (1969) reported that green-wood cuttings taken from young seedlings and about 10-year-old grafts of Allahabad Safeda guava produced 100 and 90% rooting. According to Pereira *et al.* (1983), soft-wood cuttings with 2 nodes and 4 leaves rooted beter than semi-hard-wood cuttings when treated with NAA at 2000 ppm. Soft-wood cuttings (15 cm long) of guava Lucknow 49, taken from terminal end of the shoot could be rooted under mist (Dhua *et al.*, 1982). Rooting in hardwood cutting was very poor (1.67–4.67%) in Seedless guava, while it ranged from 18.3 to 57.5% in leaf–bud cuttings and it was highest (81.4%) in semi-hardwood cuttings. Semi-hardwood, leafy (2–6 leaves) guava cuttings are suitable for regeneration of adventitious roots under mist. Root regeneration was found better in semi-hardwood cuttings of guava Lucknow 49 than in soft-wood cuttings (Prusty, 2000).

Experimental evidences indicate that there exists a synergistic relationship between phenolic substances and auxins in root regeneration from cuttings. Reddy and Majumder (1978) reported that treatment with rutin *o*-coumeric acid, quercetin, unbelliferone and syringic acid at 2000

ppm, each in combination with 5000 ppm IBA, gave 87% rooting. Dhua *et al.* (1982) obtained 93.3% rooting in semi-hardwood cuttings under mist with *p*-hydroxybenzoic acid (200 ppm) and IBA (5000ppm) treatment as quick dip.

Leafy semi-hardwood cuttings produced maximum percentage of rooting when preconditioned with etiolation (10 days) + 10 days sunlight and treated with IBA at 3000 ppm, followed by girdling (20 days before taking cuttings) + IBA at 3000 ppm (Mitra, 1996). Pre-treatment of stock plants (Lucknow 49) with ethrel at 200 ppm followed by treatment of semi-hard cutting with IBA at 2500 ppm resulted into maximum percentage of rooting, number of primary roots per cutting and increased the length of longest root (Prusty, 2000). Although success of root cutting in guava has been reported (Shanmugavelu, 1987), its use in commercial scale is very limited because of the availability of other suitable easier techniques.

Air-layering

Guava is commercially propagated by air-layering. One-year-old shoots of 1 cm diameter are selected for air-layering. A ring of bark of 2.5–3.0 cm length is carefully removed below the node and covered with moist sphagnum moss or a rooting medium of moist soil : leaf mould or compost 1:1. Root inducing hormone (auxins) may be applied in lanoline paste at the upper end of the cut. It is then wrapped with polyethylene sheet and tied carefully at both ends. Rooting occurs in 30–40 days in monsoon. Rainy season has been found to be better than spring for air-layering. The

Air-layering in guava

layered shoots are then severed from the mother plants and planted in the nursery-beds.

Application of auxins has been found to increase the percentage of success in air layers. Bhujbal (1972) reported that treatment with IBA at 3000 ppm in guava Sardar gave 86.6% rooting and 76.6% survival. Cent per cent success in rooting could be achieved by treament with 10000 ppm IBA and NAA at 1:1 proportion (Bhandary and Kologi, 1960). Sharma *et al.* (1974) opined that application of a mixture of IBA and NAA to air-layers was more effective than either of the chemical.

Bhatt and Chundawat (1982) reported that ringing of branches followed by etiolation by wrapping with black polyethylene on ringed portion 6–7 weeks before the application of rooting medium proved effective in adventitous root formation. Black polyethylene wrappers have been found to be better than white wrappers in respect of rooting and growth of layers (Singh *et al.*, 1995; Patel *et al.*, 1996).

Sharma *et al.* (1991) reported that air-layering carried out on 10 July and treated with IBA (10,000 ppm) caused highest percentage of success and number, length, diameter and weight of roots. Singh *et al.* (1992) obtained higher percentage of survival with 75% defoliation of the layered shoots after separation from the mother plant followed by complete defoliation. Immediate application of NAA at 9000 ppm after ringing gave highest number of primary and secondary roots and maximum fresh and dry weights of roots compared with application at 10 or 20 days later (Patel and Pasaliya, 1995). The best plant growth regulator for root regeneration was a mixture of IBA and NAA (Patel *et al.*, 1996) and best concentration was 3000 ppm (Patel *et al.*, 1996) and or 10,000 ppm (Singh *et al.*, 1995). Multiple air-layering (2 or 3/shoot) is feasible for increasing the efficiency of guava propagation (Mishra and Singh, 1995).

Mound layering or stooling

This technique has immense potential in rapid multiplication of guava plants. Air-layered plants are grown for 3–5 years at close spacing (0.75 cm × 0.75 cm) and headed back at 15 cm above the ground level in spring to induce new growth. A ring of bark of 1.5–2 cm is removed from towards the base of the newly emerged shoot in July and IBA (5000 ppm) in lanoline is applied. The basal part of the shoots are then covered up with soil for induction of rooting. The rooted shoots are separated in September and planted in nursery (Singh *et al.*, 1993). Majumder and Mukherjee (1968) reported that a 4.5 m × 4.5 m nursery bed can produce at least 300 rooted shoots every year with cent per cent survival. The stools can be reused for multiplying plants every year.

Dutta and Mitra (1991) obtained 100% rooting of stools of guava

Stooling in guava showing different treatments

Harijha with etiolation and IBA treatments as well as in control (without use of growth regulator), but with localized etiolation (25 mm wide black adhesive tape was applied to the shoots at 30 cm from the apex) or no etiolation, rooting only occurred with IBA at 5,000 ppm (or in case of no etiolation, IBA at 3,000 ppm plus PHB). Treatment with IBA (5,000 ppm) + PHB (200 ppm) resulted in maximum number of roots in all etiolation treatments. The highest rooting percentage and rate of survival were obtained with IBA (4,500 ppm) + NAA (400 ppm) applied in lanoline paste to the rings of shoots arising from the stools. Saroj and Pathak (1994, 1998) observed that treatment with IBA + NAA (each at 7,500 ppm) induced the best rooting in *P. chinensis, P. cujavillis*, *P. molle* and *P. cattleianum* stools with a high degree of establishment (82–99%) of rooted shoots under field conditions, whereas in *P. friedrichsthalianum* very shy rooting was obtained with the same treatment and field establishment was absolutely nil.

Grafting

Approach grafting is reported to be in practice for multiplication of guava plants in India since long back (Cheema and Deshmukh, 1927; Mitra and Bose, 1990). Though this technique gives very high percentage of success (about 95%), this is more cumbersome, expensive and requires skilled persons (Mitra and Bose, 1990; Sinha *et al.*, 1993).

The side wedge method of grafting is rather more popular technique (Nakasone and Paull, 1998) in guava propagation than approach grafting.

Several workers have suggested that veneer grafting has many advantages over approach grafting (Singh, 1972; Mukherjee and Majumder, 1983; Mitra and Bose, 1990). In veneer grafting, scion wood is defoliated about 10–14 days prior to severing from the mother plant. This encourages the axillary buds to develop and accelerates the growth process when grafted on stock plants. Green quadrangular scion of current season's growth gives better union formation than brown corky previous year's growth (Sinha *et al.*, 1993). Mukherjee and Singh (1965) reported that grafting in March, May or June was more successful, while Bhandary and Mukherjee (1970) obtained higher (85%) percentage of bud take in July than in March, April, June and August. According to Rao and Kaul (1977) the scions were in ideal condition for grafting during July and 2-month-old scions were found better than 4-month-old scions (Sinha *et al.*, 1993). Seventy per cent success could be achieved by soft wood grafting (Amin, 1978).

Budding

Budding is preferred to grafting as bud take is faster and each bud on a scion or bud wood is a potential plant. Several techniques of budding such as Forkert, shield, patch and chip are in use in guava (Mitra and Bose, 1990). Selection of a proper rootstock is the prerequisite of achieving success in budding. Shoots with a diameter of more than 12–20 mm or greater is suitable for budding. The rootstock is prepared by removing side growth up to 20–25 cm from the stem. Buds should be collected from shoots having brown colour and leaf scars (Sinha *et al.*, 1993).

Out of various methods tried, Forkert budding is considered to be the best (Sinha *et al.*, 1993). In a comparison of different budding techniques, Srivastava (1962 a) observed that Forkert budding in February–March using buds from previous season's growth on one-year-old stock gave 92% success, while it was 32% in shield budding. Cent per cent bud take could be obtained by Forkert and patch budding in rainy season, while shield budding was least sucessful (Srivastava, 1962 b). The ideal time for budding was in July, though good results have been obtained in August and February (Sinha *et al.*, 1993). Srivastava (1964) stated that success in February budding could be increased by transplanting them in shade. The failure in shield and ring budding may be ascribed to quick drying of bud before union formation (Krishnamurthy, 1965). Patch budding in May also gave considerable percentage of success (Moti *et al.*, 1976). Above 80% success could be obtained in patch budding when performed in May (Mehrotra and Gupta, 1984; Gupta and Mehrotra, 1985; Kaundal *et al.*, 1987) which might be due to higher summer temperature that favoured callus formation (Kaundal *et al.* 1987).

ROOTSTOCK

The information available on the influence of rootstocks in guava is scanty (Shanker, 1967). The species *P. cujavillis*, *P. molle*, *P. cattleianum* and *P. guineense* can suitably be used as rootstock (Mitra and Bose, 1990). Presently guava is propagated on seedling rootstocks·(Singh *et al.*, 1993). The Chinese guava (*P. friedrichsthalianum*) is reported to be resistant to wilt disease and a compatible rootstock with dwarfing effect which can be exploited commerically (Edward and Shanker, 1964). Teaotia and Phogat (1971) observed that trees grafted on *P. pumilum* had a dwarfing effect and *P. cujavillis* produced largest but non-uniform and rough-skinned fruits. Based on anatomical indices, Saroj *et al.* (1997) categorized *P. chinensis* as dwarf, *P. molle* as semi-dwarf and *P. cujavillis* and *P. cattleianum* as vigorous rootstocks. The fruit yield of Allahabad Safeda on *P. cattleianum* rootstock was higher but TSS, total and reducing sugar contents were maximum on *P. cujavillis* (Singh *et al.*, 1976).

A potentially dwarf aneuploid no. 82 rootstock of guava has been identified at IARI, New Delhi, through a selection made out of 48 different aneuploid seedling rootstocks (Sharma, 1982) that could induce substantial dwarfing of Allahabad Safeda in terms of plant height, plant spread and tree volume. The overall yield/unit volume of plant was highest in aneuploid no. 82 compared with Allahabad Safeda grafted on Allahabad Safeda and own rooted Allahabad Safeda which indicated a strong potentiality of its being used as a dwarfing rootstock on commercial scale for increasing the production and profitability of guava orchards (Sharma *et al.*, 1992). The side shoots that emerge from the rootstock at early stage in budded or grafted plants should be removed as and when noticed (Mitra and Bose, 1990).

MICROPROPAGATION

In-vitro propagation methods of guava have been standardized for rapid multiplication. Shoot proliferation from somatic tissue of mature trees have been reported by Jaiswal and Amin (1986); Amin and Jaiswal (1987). Maximum shoot proliferation was noted in medium containing BA (4.5 mM) and root regeneration was seen on subculturing excised shoot on half strngth MS medium with sucrose (1.5%), IBA (1 mM), NAA (1 mM) and 1 g/litre activated charcoal (Amin and Jaiswal, 1987). Amin and Jaiswal (1988) and Jaiswal and Amin (1988) reported a micropropagation method for guava Chittidar using nodal explants of field-grown adult trees. Agitation of explants in 0.5% polyvinyl pyrrolidone and 2–3 changes of medium for initial 10–15 days were essential for

establishment of cultures. Modified MS medium containing 1 mg/litre BA was found to be best when axillary buds grew out within 3–4 weeks. On transfer to a fresh medium of the same composition, these shoots attained 3–5 cm in length and had 4–6 nodes after 4 weeks of culture. Nodal segments taken from *in-vitro* proliferated shoots gave rise to 2–4 shoots by precocious axillary branching without an initial lag period. By repeated subculture, a large number of shoots proliferated with a shoot multiplication rate of 3- to 4-fold per subculture. Shoots obtained from the proliferation stage were rooted on half-strength MS medium containing IBA and NAA. Rooting rate was about 33% in initial cultures and 70–90% in shoots of 5th and subsequent subcultures. Regenerated plantlets were successfully established in soil under field condition.

Siddique and Farooq (1996) reported that *in-vitro* cultures of guava exude phenolic compounds into medium that hamper the growth. They also obtained the highest frequency of shoot production from nodal explants cultured on MS medium supplemented with benzyl aminopurine (BAP) at 1 mg/litre and polyvinyl polypyrolidone (PVPP) at 250 mg/litre. Callus cultures using preclimacteric fruits on MS medium supplemented with 0.01 mg IAA/litre, 0.01 mg 2, 4-D/litre and 2.87 mg kinetin/litre resulted in a high relative callus growth rate (Madhavi *et al.*, 1992).

7

Orchard Management

PLANTING AND PLANT DENSITY

THE field should be cleared, deeply ploughed, harrowed and levelled. In hilly terrain, planting is done in terrace to prevent soil erosion.The pits of 1 m × 1 m × 1 m size are dug before monsoon at appropriate distance and should be kept exposed to sun for 10–15 days to kill the soil-borne pathogens. Pits are filled with top soil mixed with 25–30 kg of well-decomposed farmyard manure or compost and insecticides like chlorpyrifos. In general, guava is planted in square or rectangular system in plain areas and along the contour in hilly regions. The ideal time for planting is with the onset of monsoon, i.e. July–Septembr. However, it can be planted during spring season, i.e. February–March with irrigation (Chandra and Chandra, 1997).

Traditionally, guava is planted in square system at a distance of 6 m × 8 m. The distance between trees has strong influence on growth, nutrient uptake, yield and fruit quality. Guava is a relatively fast-growing tree with spreading growth habit. In Australia, the recommended spacing for guava is 4.0 m × 6.0 m, accommodating about 416 trees/ha (Nakasone and Paull, 1998).

Recent trends in guava cultivation is planting at a closer spacing for obtaining higher yield per unit area. However, regular pruning and thinning are considered as prerequisites for high-density planting of guava. In Taiwan, around 600–1000 trees are planted in a hectare in north-south orientation and are reported to produce higher yield in the first 5 years. Several workers reported that high plant density caused decrease in fruit weight and size but the yield per unit area was increased considerably (Mitra *et al.* 1984; Kundu *et al.*, 1993). In an experiment on high-density planting, Chundawat *et al.*, (1992) observed that planting of Allahabad Safeda trees at 6 m × 2 m and managing them by hedge-row system produced highest yield per hectare with better quality fruits. However, per tree yield was reduced as compared with 6 m × 6 m, while maximum

yield per hectare was obtained from trees spaced at 2 m × 4 m followed by those at 6 m × 6 m (Kalra *et al.*, 1994). A long-term trial was conducted at Central Horticultural Experiment Station, Ranchi, on Allahabad Safeda, planted in 1981. The treatments included 4 planting system-cum-densities, viz. square system (5 m × 5 m, 400 trees/ha), hedge row system, (2.5 m × 5 m × 5 m, 800 trees/ha), double-hedge row system (5 m × 2.5 m × 5 m, 530 trees/ha) and paired planting (2.5 m × 2.5 m × 2.5 m, 1,060 trees/ha). The results revealed that growth characteristics were significantly influenced by planting systems-cum-densities. The girth and volume showed decreasing trend with increasing tree density while tree height increased with increasing tree density (Table 4). The maximum fruit weight was recorded in highest plant density. Yield of individual tree showed decreasing trend, whereas yield per hectare showed increasing trend with increasing tree densities (Kumar and Singh, 2000). The results of the experiment concluded that paired planting (1,060 trees/ha) is most beneficial under rainfed conditions.

Table 4. Effect of planting systems-cum-densities on growth and yield of guava Allahabad Safeda (mean of 5 years 1988–92)

Planting density (trees/ha)	Tree girth (cm)	Tree height (m)	Tree volume (m^2)	Fruit weight (g)	Yield (kg/tree)	Yield/ha (kg/ha)
400 (square system)	37.8	3.44	20.65	130.3	20.54	8,212
800 (hedge row system)	35.3	3.74	16.36	108.3	14.87	11,868
530 (double hedge row system)	36.6	3.52	18.48	118.4	17.52	9,065
1,060 (paired planting)	34.4	4.15	15.09	104.2	12.62	13,697
SEm (±)	0.42	0.06	0.67	2.24	0.46	2.56
CD (5%)	1.28	0.19	2.03	6.74	1.38	7.78

In ultra high-density planting (73,000 plants/ha) trees grew in height with few laterals although the lowest density (27,000 plants/ha) produced highest yield (Mohammed *et al.*, 1984). Such a high density planting does not seem to be appropriate in guava with spreading growth habit (Nakasone and Paull, 1998).

TRAINING AND PRUNING

Guava plants can be pruned and trained to any dimension or pattern the grower wishes. It can be trained into a large, low-hanging bush to permit hand harvesting or into a small tree with a single trunk to permit mechanical harvesting. A properly pruned and trained tree can be confined

to a foliage canopy approaching 4 m in radius. This radius can be maintained by judicious pruning in conjunction with crop cycling.

Training of guava trees has been found to improve yield and fruit quality (Mitra and Bose, 1990). The primary objectives of training are to develop single trunk tree with well-spaced scaffold branches to form a strong framework and for bearing a heavy crop without damaging the branches. The trees should be kept open for better penetration of sunlight leading to more number of shoots and higher yield.

The open centre training system can be practised in guava. The tree is allowed to grow undisturbed during the initial years, which is then headed back at 60–90 cm height and 3–4 well-spaced, vigorously growing laterals, projected at different directions are retained. The laterals are subsequently pruned by cutting one-third to half of their length after 3 months. After making the initial framework, 2-side shoots are permitted to grow initially and after 3–4 years subsequent doubling of selected branches is continued.

Guava trees are also trained in delayed open centre or modified leader system, in which 2-tier of framework are prepared and the centre is kept open at a height of 140 cm. Four side-shoots are retained in this system and only one-third of their length is pruned. For obtaining the second tier, tree is headed back at a position close to an outward bud. It was found that training reduced the canopy area up to 11.1% in open centre and 27.6% in delayed open centre giving thereby an opportunity to accommodate more number of plants per unit area.

In Maharashtra and West Bengal, a somewhat peculiar system of training is followed. The branches are bent downwards by mechanical stress resulting into forcing of dormant buds to produce new shoots and the yield is increased. However, this method should not be practised year after year as it decreases the yield considerably in subsequent years (Mitra and Bose, 1990).

Guava bears flowers on current season's growth. Therefore, a light annual pruning is considered to be essential to boost up new vegetative shoot emergence. The length of flowering shoots tended to decrease with delay in time of pruning but increased with the increasing severity of pruning irrespective of season (Bajpai *et al.,* 1973; Gopikrishna, 1981; Dhaliwal *et al.,* 1998). An increase in shoot length due to severity of pruning might be due to elimination of growing points which in turn encouraged the length of remaining shoots (Dhaliwal *et al.*, 1998). Pruning by heading back encourages new, long, whip-like shoot growth with sparse flowering compared with cutting at fork (Nakasone and Paull, 1998). All dead, diseased, crowded growth and suckers coming up from the base and sides of the framework should be pruned back annually (Mitra and Bose, 1990).

The intensity of pruning has considerable effects on bearing of guava

trees. Bajpai *et al.* (1973) and Gopikrishna (1981) reported that severe pruning has an adverse effect on productivity. Removal of terminal 15 and 30 cm of branches adversely affected flower production and yield (Sheikh and Hulmani, 1993, 1994). Pruning at an intensity of 25% in February could regulate fruit yield without affecting fruit quality under high-density planting (Chandra and Govind, 1995).

Time of flowering in guava can also be altered by suitable pruning (Sundarajan and Muthuswamy, 1964). With the increasing pruning intensity the rainy season yield decreases and one-leaf-pair pruning proved superior to the other pruning treatments for flower-bud initiation and fruit yield of the winter crop (Lal *et al.*, 1996). Duration from shoot emergence to flower bud emergence and anthesis to fruit maturity decreases with increase in severity of pruning as well as in delaying pruning time. However, duration from flower-bud emergence to anthesis decreases with increase in intensity of pruning but remained unaffected by the date of pruning (Dhaliwal *et al.,* 1998). Severe pruning in January produces greater shoot growth and leaf area by April and August under Dharwad, Karnataka, condition (Sheikh and Halmani, 1997).

Manuring and fertilization

Guava responds well to both inorganic fertilizer and organic manure applications (Mitra and Bose, 1990; Pereira and Mitra, 1999). Emphasis on nutrient application to guava trees was given long back in 1949 by Naik, as guava bears fruits mostly on newly emerged shoots. Application of nutrients encourages vegetative growth (Hayes, 1974).

Nitrogen: The dificiency of N caused stunted growth of the plant. The leaves showed purple coloured patches on both sides of mid-rib and principal veins. Increasing the rate of N was reported to increase the growth, yield and fruit quality (Kaj *et al.,* 1989; Kumar *et al*., 1996a). Under rainfed condition of Bihar, Kumar *et al.* (1996a) suggested application of 300 g N/tree/year for 5–6 years old tree and 600 g N/tree/year for 7–8 years old tree of Allahabad Safeda. Mitra and Bose (1985) found highest fruit yield of 3-year-old Sardar guava with 260 g N/tree/year in West Bengal while Wagh and Mahajan (1985) recorded highest yield with 600 g N/tree/year in 5-year old Sardar guava.

Phosphorus: Deficiency of P resulted in stunted plant height, reduced number and size of leaves and premature defoliation. Deficiency of P also resulted into development of typical foliage symptoms of leaf bronzing and the critical level of phosphorus was considered to be 0.03% on dry-weight basis under sand culture (Tiwari and Tiwari, 1993). Experimental results indicate the positive influence of phosphorus on growth, yield and quality of guava fruits. Kumar *et al.* (1995) reported that treatment with over 500 g P_2O_5/tree/year improved the fruit quality but maximum net

returns per tree was obtained with 600 g P_2O_5/tree/year.

Potassium: The deficiency of K also reduces plant growth, leaves show necrotic patches which are mainly concentrated more towards the margin, tip and base. The role of K on fruit yield and quality is well documented in guava (Rajput *et al.*, 1978; Mitra, 1987; Kumar *et al.*, 1996b). Natale *et al.* (1996b) found that tree growth, fruit weight and yield were significantly increased at K rate up to 400 g K_2O/tree/year, while TSS, ascorbic acid, reducing sugars and pectin contents of fruit juice increased significantly with rising K_2O application up to 500 g/tree/year.

Fertilizer recommendations

Singh and Srivastava (1978) suggested to apply a fertilizer dose of N:P:K at 60:40:40 g/plant/year in Uttar Pradesh. A dose of 260 g N, 320 g P_2O_5 and 260 g K_2O/plant/year in 2 equal split doses in January and August for 3–4 years old Sardar guava in the alluvial plains of West Bengal was suggested. Maximum yield in Tamil Nadu was obtained with 1.0 kg each of N, P and K application/tree.

Application of 600 g N and 300 g each of P_2O_5 and K_2O along with 25 kg of farmyard manure gave highest yield in 5-year-old Sardar guava grown in Maharashtra (Wagh and Mahajan, 1985). At Ranchi, Bihar, the highest yield was obtained with 500 g N, 300 g P_2O_5 and 600 g K_2O/plant/year (IIHR, 1988). Plant height, canopy diameter, trunk girth, total fruit numbers and fruit weight of three- and-a-half-year-old Allahabad Safeda guava trees did not differ significantly in response to application of varying levels of NPK (15:15:15). However, fruit yield increased up to 1.0 kg/tree rate but declined with further increase in the rates (Aielaagbe, 1989). A fertilizer dose of N:P_2O_5:K_2O at 900:600:600 g/tree/year was recommended by the IIHR, Bangalore for obtaining maximum yield (IIHR, 1990). Experiments conducted on standardization of NPK requirements of guava in different states of the country have indicated that this depends on many factors such as variety, climate, soil type, cropping pattern and intensity. Following are some of the recommendations worked out by different workers in different states.

State	N, P, K (g/tree)
West Bengal	260–454 g N + 160–260 g P_2O_5 + 260 g K_2O
Uttar Pradesh	60 g N + 40 g P + 40 g K
Tamil Nadu	1 kg N + 1 kg P + 1 kg K
Bangalore	900 g N + 600 g P + 600 g K
Bihar	500 g N + 300 g P_2O_5 + 300 g K_2O
Maharashtra	600 g N + 300 g P_2O_5 + 300 g K_2O

Mitra and Bose (1985) suggested to apply the fertilizers in January

and August in 2 equal split doses, however, 70% of N along with full K in June and 30% N with full P should be applied in September (IIHR, 1990).

Foliar nutrition

Foliar application of N to guava trees increased percentage of flower, fruit setting and yield (Tiwari *et al.*, 1968). Spraying of 1 or 2% urea + 2% triple superphosphate + 1% potassium sulphate during July (Arora and Singh, 1970a) or 3% urea along with calcium phosphate and MOP each at 1% (Chhonkar and Singh, 1981a) caused marked increase in vegetative growth (Arora and Singh, 1970a; Chhonkar and Singh, 1981a) and also enhanced yield (Arora and Singh, 1970a; Pandey *et al.*, 1988). Singh and Rajput (1977) reported that spraying of 2 and 4% superphosphate in July and January increased the number of flower buds, yield and size and weight of fruits. Combined application of KNO_3 + $CaCl_2$+ $Ca(NO_3)_2$ each at 1% resulted considerable increase in size and weight of fruits (Singh *et al.*, 1981b). Spraying of 4–6% urea in January and July significantly increased growth, flowering, yield and improved fruit quality of Allahabad Safeda (Singh, 1985). Foliar spraying with N (3%), P (1%) and K (1%) in combination caused marked increase in shoot growth, fruit setting, fruit retention and yield (Sharma and Sharma, 1992).

Application of urea (4%) alone or in combination with SSP (2%) and GA_3 (100 ppm) on leaves significantly increased the yield per plant, but the combined spray failed to exert any influence on TSS and acidity of rainy season fruits though there was a significant improvement in ascorbic acid content (Singh and Singh, 1995). However, quality of winter season fruits was generally improved by combined spray. Spraying of $MgSO_4$ (0.4%) in February and July for rainy and winter season crops respecively, increased number of flower buds, fruit setting and fruit retention in Allahabad Safeda. Yield and quality attributing characters were improved significantly by calcium and potassium compounds and calcium nitrate (1.5%) proved more beneficial (Brahmachari *et al.*, 1997).

Pre-harvest application of 1% $Ca(NO_3)_2$ has been found to be effective in minimizing weight loss and extending storage life without deteriorating the quality (Singh *et al.*, 1981a).

Micronutrients

Various micronutrients have been found effective in regulating growth, yield and fruit quality of guava and their deficiency may cause severe set-back in growth and development of trees. Arora and Singh (1970b,c) reported that spraying of $ZnSO_4$ (0.4%) in July caused marked increase in growth, chlorophyll content of leaves and yield of guava Allahabad Safeda. Similar results were noted by Chhonkar and Singh (1981b).

Spraying of boric acid caused increase in vegetative growth and reduced degree of chlorosis (Arora and Singh, 1972). Maturity of fruits could be enhanced by the application of 0.4% $ZnSO_4$ (Arora and Singh, 1970c). Rajput and Chand (1976) observed that treatment with $ZnSO_4$ (0.3%) or boric acid (0.4%) significantly increased the size of fruits and improved the quality. Spraying of $FeSO_4$ or $CuSO_4$ at 0.2 or 0.4% in July proved effective in increasing the growth and yield of guava (Arora and Singh, 1970b, 1971).

Combined application of Mg + Zn + B (each at 0.3%) thrice a year, i.e. before flowering, after fruit setting and during fruit growth and development gave maximum yield (Ghosh, 1986). Pandey *et al.* (1988) reported that ripening could be advanced by spraying of urea (2%) + $ZnSO_4$ (0.4%) before flowering followed by subsequent spray 3 weeks after fruit setting. Copper defficient guava plants showed chlorosis and marginal necrosis of young leaves, brown pigmentation at both sides of the midrib and dieback of main and axillary shoots (Agarwala *et al.*, 1991). According to Azzay *et al.* (1994), the uptake of Fe, Zn and Mn increased with increasing S application rate up to 4 kg/fedden (1 fedden = 0.42 ha), but further increase in S dose resulted a decrease in uptake of these micro-elements.

Leaf analysis

The nutrient element composition of guava trees varies with different factors, viz. advancing age (Sanyal and Mitra, 1990; Chetri *et al.*, 1999), direction of shoot, zone of leaf sampling and position of leaf on shoot (Sanyal and Mitra, 1990), cultivar (Chetri *et al.*, 1999). It has been observed that leaves from non-fruiting shoots, in general, contained more NPK than those from fruiting shoots. Rodriguez *et al.* (1984) reported that in leaves of guava rootstock Cotorrera, the N, P and K contents decreased and Na content increased from the apex to base of shoots and these nutrients were high in non-fruiting than in fruiting shoots. The position of leaf half-way on fruiting shoots was recommended for leaf nutrient analyses. The macro-element composition of leaves has been found to decrease with the increase in age (Sanyal and Mitra, 1990; Chetri *et al.*, 1999).

Arora and Singh (1972) recommended that 50 leaves of the same age should be sampled covering all sides of tree for estimation of elements. Reports indicated that samples of 53–60 days old leaves in July and November for rainy and winter season crop, respectively, should be collected for nutrient analyses (IIHR, 1990). Dahiya and Joon (1995) concluded that a minimum of 30 leaves are required for determination of macro- and micronutrients content of leaves in guava. The seasonal changes in nutrient element composition of leaves are presented in Table 5.

Sanyal and Mitra (1990) reported that in alluvial soils of tropical climate, the leaf N content of guava Lucknow 49 (Sardar) increased from March to August, which afterwards decreased and again increased from December to January. The variations in P and K contents were not very pronounced. The newly-emerging leaves contained higher N, P and K than older ones. According to Natale *et al.* (1994), leaf N content in guava Rica was higher at flowering than at begining of fruiting and sampling during flowering gave optimum correlation with the N rate applied, fruit production and leaf N:K ratio. Significant variations in foliar Fe and Mn concentrations have been reported due to seasons, while Cu and Zn concentrations remained unchanged. The fluctuations of micronutrient concentrations were found less between November and December, indicating that this was ideal time for sampling (Chetri *et al.* 1996). The nutrient element composition of leaves also varies with cultivars (Chetri *et al.*, 1996; 1999).

Table 5. Changes in nutrient composition of guava leaves as influenced by season and cultivars*

Month	Dry weight (%)					ppm			
	N	P	K	Ca	Mg	Fe	Cu	Zn	Mn
April1990	2.06	0.12	0.81	0.34	0.37	190.0	6.0	38.0	134.7
May 1990	1.92	0.19	0.75	0.21	0.32	254.6	29.0	45.3	90.0
June 1990	1.90	0.12	0.50	0.30	0.34	209.1	11.7	42.3	100.3
July 1990	1.84	0.12	0.45	0.45	0.38	154.6	23.6	31.3	135.3
August 1990	1.81	0.10	0.38	0.54	0.48	209.1	6.7	32.3	176.7
September 1990	1.56	0.14	0.44	0.83	0.55	181.8	6.3	55.3	177.7
October 1990	1.74	0.15	0.51	0.78	0.56	200.0	29.0	32.3	174.0
November 1990	1.82	0.17	0.56	0.76	0.56	272.7	10.3	51.3	256.0
December 1990	1.70	0.12	0.58	0.72	0.52	254.6	11.7	29.7	234.3
January1991	1.60	0.07	0.58	0.63	0.46	190.9	9.0	33.7	219.7
February 1991	1.51	0.19	0.63	0.63	0.41	236.4	9.3	52.3	143.7
March 1990	2.08	0.14	0.71	0.59	0.47	281.6	12.7	44.3	262.7
LSD (P = 0.05)	0.28	NS	0.18	0.21	0.10	75.4	NS	NS	66.9
Cultivars									
Allahabad Safeda	1.76	0.12	0.62	0.48	0.42	212.1	13.3	40.8	157.6
Lucknow 49	1.83	0.14	0.53	0.64	0.48	227.3	14.6	40.7	201.6
LSD(P=0.05)	NS	NS	0.08	0.09	0.04	NS	NS	NS	NS

*Chetri *et al.* (1996, 1999)

Experimental reports indicate that cropping intensity also influences nutrient status of guava trees. The foliar N level was reported to be lower in fruiting than in deblossomed tree, while no such pattern could be established for P, Ca and Mg contents. Variations in K content in leaf tissue were not very prominent (Khera and Chundawat, 1977). Rainy season fruiting was found to be positively correlated with leaf N and K

in July and winter fruiting with N status (Rao *et al.*, 1988).

Shigeura and Bullock (1983) recommended a tentative foliar analysis guide for fertilization on the basis of dry matter : N, 1.7%; P, 0.25%; K, 1.5%; Ca, 1.25%; Mg, 025%; Zn, 20 ppm; Mn, 60 ppm; Cu, 8 ppm; and B, 20 ppm. From a correlation studies of nutrient status of leaf with yield, Singh *et al.* (1981) reported the normal range for N (1.4%), P (0.4–0.6%), K (1.2–1.4%), Ca (1.2–3%), Mg (0.25–0.68%), Zn (25–130 ppm), Cu (50–100 ppm) and B (5–15 ppm). The leaf nutrient composition associated with maximum yield of Allahabad Safeda in Bihar was reported as 1.8–2.0% N, 0.12–0.16% P, 1.46–2.08% K, 1.13–1.69% Ca, 0.25–0.31% Mg, 266–345 mg/g Fe, 176–267 mg/g Zn and 10–13 mg/g Cu (Kotur *et al.,* 1997). Leaf N concentration of basal leaves during seed development was found inversely correlated with yield (Marin *et al.*, 1999).

Application of nutrients at different rates to tree also influence nutrient element composition of leaves. Wagh and Mahajan (1985) observed that application of N caused an increase in foliar N, P, Ca and Mg up to a certain level (600 g/tree). Similar trend was noted with P application and there was a synergistic effect of P on uptake of N, K, Ca and Mg. Potassium application failed to elevate the levels of leaf K. Treatments with higher rates of N, P and K increased the N, P and K status of leaves and stems (Mitra, 1983; Ghosh, 1991); a remarkable reduction in K level was, however, noticed under N deficiency (Mitra, 1983). Pre-harvest spraying of 2% $Ca(NO_3)_2$ resulted an increase in N, P, Ca and Mg contents of leaves, whereas K content increased even by spray at 1% concentration.

Irrigation

Guava trees are seldom irrigated in India and can withstand prolonged periods of drought (Shigeura and Bullock, 1983). However, young trees should be irrigated regularly for better establishment and quick growth (Hayes, 1974). Adequate moisture supply is needed during vegetative growth, flowering and fruit development. Young trees should be given 8–10 irrigations a year, while fully grown trees are irrigated at fortnightly interval during April–June (Mitra and Bose, 1990). Moisture stress during fruit setting period may cause severe fruit drop. Irrigation during winter was also found to be effective in reducing fruit drop and improving fruit size of winter crop (Mitra and Bose, 1990). Flowering is also influenced by water availability and heavy flowering has been reported in dry tropical belt following the onset of rainy period (Nakasone and Paull, 1998).

The best growth (earliest flowering and fruit maturity, largest fruits and highest yield in guava Sardar were recorded with an irrigation treatment of 60 cumulative pan evaporation (CPE) to a depth of 75 cm (Lal, 1996). The performance and drought tolerance capacity vary with cultivars.

Flower abscission was observed when relative water content reached 60.2% in Allahabad Safeda and 53.4% in Sardar. However, water-stressed condition significantly decreased yields in both cultivars during rainy season. It was also observed that metabolic activity was better maintained, even at a low in Sardar than in Allahabad Safeda (Singh *et al.*, 1997).

For obtaining higher yield with quality fruits judicious water management in bearing guava trees seems to be essential. Guava trees irrigated at 1.0 and 0.8 IW/CPE ratio recorded highest consumptive use and annual pooled as well as *bahar*-wise fruit yield, which might be ascribed to more wet soil surface leading to high evaporation and transpiration, more uptake of nutrients from the soil resulting in better vegetative growth and more photosynthate production. The mean *bahar*-wise consumptive use was higher in *ambe bahar* compared to *mrig bahar* that might be due to higher temperatures in combination with lower relative humidity in *ambe bahar*. On the other hand, mean fruit yield was more in *mrig bahar* compared to *ambe bahar* (Table 6). Number (4) and depth (300 mm) of irrigation were lower in *mrig bahar* than 12 irrigations and 900 mm depth in *ambe bahar* (Patil and Patil, 1998a,b). Drip irrigation is becoming popular day by day to replenish daily water loss, i.e. 25–50 mm/week (Nakasone and Paull, 1998). This method has been proved to be very economic and can supply sufficient water directly to the root zone of the tree leading to minimum loss and maximum utilization of irrigation water.

Mulching

Use of mulch helps in conserving soil moisture, regulating soil temperature and controlling weed growth. Mulching can be done either with black polyethylene sheet or with organic materials. Mulching with rice husk, rice straw, and water hyacinth (*Eichhernia crassipes*) reduced the weed population and increased yield in guava Allahabad Safeda, Banarasi and Seedless in comparison to the control (Borthakur and Bhattacharyya, 1999a).

In general, all the mulching treatments significantly increased the height and fruit yield compared with the control. Mulching with paddy husk proved its superiority over others in respect of number of leaves/shoot and fruit yield, while maximum increment of plant height was noted with paddy straw (Borthakur and Bhattacharyya, 1999a). The better performance of trees with organic mulches might be due to their combination of plant nutrients and organic matter in soil besides other usual roles (Borthakur and Bhattacharyya, 1999b).

Intercropping

Generally guava is planted at wider spacing (5–6 m × 5–6 m) and

Table 6. Mean consumptive use, consumptive-use efficiency , evapotranspiration ratio and fruit yield (kg/tree) of guava as influenced by different irrigation regimes (1987-89)**

	CU*			Fruit yield			CUE			ETR			No. of irrigation			Depth of water applied (mm)		
	A	B	Annual	A	B	Annual	A	B	Annual	A	B	Annual	A	B	Annual	A	B	Annual
IW/CPE ratio																		
I_1 (0.4)	743.6	593.2	1310.3	44.47	81.8	126.26	0.6	1.38	1.10	1.67	0.7	0.96	6 (20-50)	2 (38-38)	4 (19-50)	450	150	300
I_2 (0.6)	855.8	672.6	1509.7	96.55	100.0	195.44	1.01	1.47	1.41	0.99	1.0	0.78	10(11-31)	3(21-29)	6 (11-31)	75	225	450
I_3 (0.8)	1143..9	783.5	2012.0	116.30	110.00	226.31	1.02	1.40	1.17	0.98	0.7	0.89	13(8-25)	4(16-22)	18(8-25)	975	300	1350
I_4 (1.0)	1322.6	841.9	2284.5	82.34	100.1	182.41	0.62	1.19	0.83	1.61	0.8	1.23	16(6-21)	5 (14-20)	21 (6-21)	1200	375	1675
S.E. ±				6.21	4.7	2.83												
C.D. at 5%				17.97	13.6	8.81												
Deviation																		
D_0	1102.0	667.4	1781.8	86:30	94.8	181.85	0.78	1.42	1.14	1.28	0.7	0.95	12 (9-28)	3 (27-32)	14 (9-32)	900	225	1125
D_1	1112.1	785.3	1938.9	81.35	100.4	181.75	0.73	1.28	1.07	1.37	0.9	1.06	13 (9-32)	4 (17-29)	17 (9-32)	975	300	1225
D_2	953.6	677.2	1663.7	80.40	103.40	183.76	0.84	1.53	1.22	1.17	0.7	0.86	10 (14-34)	3 (28-32)	14 (14-34)	750	225	1060
D_3	896.2	761.2	1732.3	81.65	92.2	173.85	0.91	1.21	1.04	1.10	0.8	0.99	11 (13-31)	4 (17-23)	15(11-30)	826	300	1225
S.E. ±				6.21	4.7	2.83												
CD at 5%					17.96	13.6	8.81											
Mean	1016.5	772.3	1779.1	82.42	97.7	188.11	0.81	1.36	1.12	1.31	0.8	0.96	12 (12-32)	4(22-28)	15 (11-32)	900	300	1125

Figures in brackets indicate irrigation interval (days); A, *Ambe bahar*, M, *mrig bahar*
*Included effective rainfall
**Patil and Patil (1998 a,b)

trees require 4–5 years to cover the entire area. During this period the space between rows can be utilized for growing several intercrops. Intercropping inside guava orchard with vegetables (Hugar *et al.*, 1991) and fodder crops (Gill, 1988) can fetch better return to growers besides generating more employment (Hugar *et al.*, 1991). Several intercrops like cauliflower, peas, frenchbean and senji in *rabi* season; cowpea, clusterbean, blackgram and greengram during *kharif* season and cucurbits during summer can be grown in guava orchards at pre-bearing stage. In Uttar Pradesh, papaya is commonly grown as a filler crop, while pineapple and strawberry could be other possible crops (Chundawat, 1993). Under dryland conditions, stylo cover crop gave an additional yield of 21.2 tonnes/ha (Gill, 1988).

Weed control

Weed control is essential during initial phase of orchard establishment. The shade provided by the canopy of grown up orchard checks weed growth. The plant height of young guava seedling is checked by 50% due to weeds like *Cynodon dactylon* (Maurya and Shankar, 1982). It has been reported that application of herbicides Asulam (8 kg a.i./ha) and Bromacil (2 kg/ha) caused initial chlorosis of leaves but recovered completely later on (Puente and Guzman, 1979). Herbicides are generally not recommended in young plantation as there may be severe damage by spray drift or direct contact (Nakasone and Paull, 1998). Pre-emergence use of Diuron (1.6 kg/ha), Oryzalin (1.67 l/ha), Simazine (1.6 kg/ha) or Atrazine (1.6 kg/ha) showed good control of weeds in guava orchards (Martinez and Pereira, 1984). Increased yield and improvement of fruit quality of L 49 (Sardar) guava were recorded by pre-emergence application of Atrazine (5 kg a.i./ha) or Oxyfluorfen (0.50 kg a.i./ha).

8

Flowering, Fruiting and Crop Regulation

FLOWERING

In general, guava tree flowers twice a year, i.e. in April–May and August–September, of which fruits ripen in rainy and winter seasons (Gupta and Nijjar, 1978). Sometimes, a third flowering, although sparse, occurs in October–November (Singh and Kumar, 1993), particularly in Maharashtra and Tamil Nadu (Hayes, 1974). Mitra (1983) stated that there are 2 important cropping seasons in West Bengal, i.e. rainy (flowering in April–May) and winter (flowering in September–October). In *terai* region, 3 flowering seasons are very common (Singh and Kumar, 1993).

Floral buds appear soon after first pair of leaves mature, but there is no direct association between leaf appearance and flower production (Menzel and Paxton, 1986). Flowers occur either singly or in cymose of 2–3 at leaf axils of current (Braganza, 1990) and preceeding growth (Nakasone and Paull, 1998). The bearing twigs normally grow a few centimetres putting forth 4–5 pairs of leaves and thereafter, either flower buds start developing or twigs cease to grow till the next season. Guava requires about 30 days from flower-bud differentiation to complete development up to calyx cracking stage (Prakash, 1976). The flower buds when fully develop have 2 distinct parts, viz. ovoid proximal or adnate and distal free part which is ovoid or round and slightly pointed at apex (Sehgal and Singh, 1967).

Both terminal and lateral flowerings have been reported, occassionally mixed type flowering also occurs. The blooming period ranges from 28 to 45 days depending on cultivar, season and region of growing (Mitra and Bose, 1990). The flowers consist of a superior calyx with 5 lobes and the corolla consists of 6–10 petals arranged in one or two whorls. The androecium consists of 160–400 thin filaments carrying bilobed anthers, closely packed together. The gynoecium consists of an inferior ovary syncarpus with axil placentation and subulate style. The style is smooth and bearded at the summit (Kahlon *et al.*, 1987a).

Flowers open between 05.00 and 07.00 AM (Kundu and Mitra, 1994a)

in West Bengal and 6.00 and 7.30 AM under north Indian condition, except in Seedless where it is delayed by 1–2 hours (Kundu and Mitra, 1994a). Dehiscence of anthers occurs between 05.30 and 07.30 AM except in Seedless (between 07.30 and 08.30 AM) (Kundu and Mitra, 1994a). Nakasone and Paull (1998) stated that dehiscence occurs at anthesis or shortly before. Floral morphology favours self-pollination, but considerable cross-pollination also occurs. Pollen viabi-lity was found 50.37% for Seedless, but in other cultivars it was 86.24–94.32% (Kundu and Mitra, 1994). Guava generally have pollen with high rates of germination (Hirano and Nakasone, 1969), except for triploid clones, viz. Indonesian Seedless (Nakasone and Paull, 1998).

The pollen is reported to possess round and large grains. Pollen-grains are usually triangular in shape, though some irregular and pentagonal shaped pollens are observed in Seedless cultivar. Pollen-grains are most viable on day of full bloom and pollen viability is generally higher in spring than in autumn (Kahlon *et al.*, 1987b). Bees are natural pollination agents.

Some degree of self- and cross-incompatibility among guava clones are not very uncommon which might be ascribed to the failure of pollen tube growth in style. Ito and Nakasone (1968) reported that self-pollinated Beaumont produces cent per cent fruit settingting while cross-pollination with other cultivars resulted 60 and 80% fruit setting (Table 7).

Table 7. Cross-compatibility of guava clones as percentage mature fruits from self- and cross-pollination*

Female parent	Fruit setting Male parent				
	7197	7199	Beaumont	Lucknow	Indonesian Seedless
7197	67	33	33	29	0
7199	33	64	50	50	0
Beaumont	62	67	100	100	0
Lucknow	57	33	33	27	0
Indonesian Seedless	57	14	0	0	0

*Ito and Nakasone (1968)

Exogenous application of some chemicals can regulate flowering in guava. Spraying of ethrel (1 ml/litre) caused greater ethylene-forming enzyme activity in leaves leading to maximum number of flowers and fruits (Castelan-Estrada and Becerril Roman, 1994). Chandra and Govind (1994) obtained maximum flowering by spraying of urea (25%) and ethrel (2000 ppm). Earliest flowering and maximum number of flowers were recorded by spraying of CCC (500 ppm) (Brahmachari *et al.*, 1996).

FRUIT SETTING AND PARTHENOCARPY

The natural fruit setting in guava is quite high (80–86%, of which only 34–36% fruits reach maturity (Mitra and Bose, 1990). In Seedless, only 6% fruits attain maturity (Kundu and Mitra (1994b) observed a slight increase in fruit setting during summer compared with autumn (Table 8). Fruit setting in triploid guava is satisfactory when grown together with diploid clones as a pollen source (Nakasone and Paull, 1998). Fruit formation is first noticeable only 12 days after flowering.

Table 8. Fruit setting (%) in different guava cultivars*

Cultivar	Summer	Autumn	Cultivar	Summer	Autumn
Allahabad Safeda	71.2	68.8	Chittidar	71.2	69.6
Allahabad	77.6	62.4	Harijha	66.4	64.8
Apple Colour	80.8	59.2	Kerala	68.8	62.4
Banarasi	75.2	64.0	Sardar (L-49)	77.6	74.4
Baruipur	74.4	70.4	Seedless	42.4	40.8
Behat Coconut	66.4	65.6	Supreme	71.2	60.0

*Kundu and Mitra (1994b)

The fruit drop in guava may occur due to vaious physiological and environmental factors (Mitra and Bose, 1990). Nakasone and Paull (1998) stated that post-setting drop may occur as a result of factors other than pollination, such as, blossom end rot, caused by calcium deficiency. According to Rajput *et al.* (1977), spraying of GA_3 (15 or 30 ppm) in January proved effective in increasing fruit retention and yield. Foliar application of CCC (50 ppm) and PCPA (50 ppm) twice (one before flowering and a month after fruit setting) significantly enhanced fruit setting in Sardar guava (Brahmachari *et al.*, 1995).

Attempts have been made to induce parthenocarpy in guava by using of growth regulators. Fruit setting and fruit quality are improved and fruits contain fewer seeds with 50 mg/litre gibberellic acid (Nakasone and Paull, 1998). Treatment of unopended, emasculated and styles cut off flowers with GA-lanoline mixture (applied on cut surface of styles) induced parthenocarpy and increased fruit size, but the fruits were slightly malformed (Shanmugavelu, 1962).

CROP REGULATION

Guava bears fruits almost round-the-year. However, 2 distinct seasons of flowering—spring-summer (April–May) and rains (August–September)—occur from which fruits ripen during rainy and winter season, respectively. Shikkamany *et al.* (1986) observed that guava bears thrice in a year,viz. rainy, winter and summer which constitute 70, 27 and 3%. This is quite

evident from that heaviest flowering has always been obtained in summer season (Kundu and Mitra, 1997; Singh and Reddy, 1997; Singh and Singh, 2000). Because food reserved is already exhausted in flowering and vegetative growth during summer, the rainy season flowering for winter cropping is always less (Rathore, 1975). The rainy season crop of guava is poor in fruit quality and is affected by many insect pests compared to winter crop. The winter season fruits which ripen from late-October to late-January are superior in quality, free from diseases and pests and fetch higher income. This requires regulation of flowering to obtain most profitable crop by withholding irrigation, root exposure, pruning and thinning of flowers. In different regions various methods of crop regulations are followed depending on climatic factors, cropping pattern, cultivar etc.

Table 9. Crop regulation by using chemicals

Location	Cultivar	Chemicals	Time of application	References
Lucknow Uttar Pradesh	Allahabad Safeda Sardar	Urea 10% KI 0.05%	30 April and 10 May (2 sprays)	Singh and Singh (2000)
Ludhiana Punjab	Allahabad Safeda	Urea 10%	3rd week of May	Singh *et al.* (1992)
Patiala Punjab	Allhabad Safeda	Urea 15%	Ist week of April, or Ist week of May and 10–15 days of first spray (2 sprays)	Singh *et al.* (1994)
Sabour Bihar	Allahabad Safeda	NAD 50 ppm	4th week of April and 2nd week of May (2 sprays)	Singh *et al.* (1993)
	Lucknow 49	NAA 250 ppm		Choudhary *et al.* (1997)
Midnapur West Bengal	Lucknow 49 (Sardar)	DNOC 10 ppm	4th week of May	Kundu and Mitra (1997)
Nadia West Bengal	Lucknow 49 (Sardar)	NAD 50 ppm	2nd week of April	Mitra *et al.* (1982)
	Harijha	Urea 10%	2nd week of April	Mitra *et al.* (1995)

Withholding irrigation from December to June or until the beginning of monsoon depending on prevailing condition at a particular location has been recommended in southern peninsular India. Withholding of water from December to June and removing the earth from around the upper roots by 10 June, and again covering it with soil and manure mixture has been suggested. Two light irrigations were also suggested before normal heavy one, if the rains did not start.

Root exposure followed by root pruning were also recommended to supress rainy season crop so as to get a good winter crop under west

Indian condition (Kaul, 1974). However, root pruning should not be done year after year as it may affect the longevity and productivity of trees.

Pruning current season's growth of spring flush to avoid rainy season crop has been advocated in northern parts of the country (Tiwari and Lal, 1984). In Haryana, pruning of 25–50% shoots at any dates of 20 April, 10 May or 30 May was found to evade flowering in rainy season and encouraged winter season flowering of Sardar guava (Dhaliwal *et al.*, 1998).

Manual deblossoming of rainy season flowers, though very effective, is not in practice which is very cumbersome, labourious and uneconomic. Flower thinning by using naphthalene acetic acid (NAA), naphthalene acetamide (NAD), 2,4-dichlorophenoxy acetic acid (2,4-D), potassium iodide (KI), 2-chloroethyl phosphonic acid (ethephon), 4,6-dinitro-o-cresol (DNOC) and urea have been tried with varying degree of success. This variation may be due to cultivars, tree condition, soil type and environment. Most of the workers are in opinion that chemical thinning is economic and it increases the winter yield as well as improves fruit quality. The results of crop regulation experiments and recommendations are given in Table 9.

9

Fruit Growth and Development

The growth curve of guava fruits has been reported to follow a double sigmoid patterns (Rathore, 1976; Dhillon *et al.*, 1987a; Selvaraj *et al.*, 1999). On the contrary, Nakasone and Paull (1998) stated that fruit growth of guava follows a simple sigmoidal curve. Rathore (1976) repored that length and diameter of fruits of Red Fleshed, Safeda, Lucknow 49 and Chittidar showed 3 distinct periods of growth. *Period I:* period of rapid growth, which started a few days after anthesis, continued for 45 days in both rainy and winter seasons, but for 60 days in spring season. *Period II*: a period of relatively slow growth of 30 days duration, except in spring season when it lasted for 60 days during this period the seeds matured and became very hard. *Period III:* an exponential increase in rate of fruit growth was observed in this period which ended with harvesting of fruits. As a result, both length and diameter of fruits increased markedly. This period continued for 30, 60 and 90 days in rainy, winter and spring seasons respectively.

Kundu *et al.* (1995) working with Sardar guava in West Bengal, classified the fruit growth into 3 district stages, viz. *Stage I*, in which fruit growth was rapid for first 50 days of fruit setting; *Stage II*, in between 50 and 90 days of fruit setting, when growth was very slow; and *Stage III*, in which an exponential increase in rate of fruit growth was noted between 90 and 120 days. The weight and size of fruits gradually increased at the first phase, then slowed down and finally increased till maturity. The duration of all 3 growth phases appeared to be inversely proportional to prevailing temperatures (Mitra and Bose, 1990). The days from anthesis to harvesting can vary from about 120 to over 220 days depending upon temperature during fruit development (Nakasone and Paull, 1998). On an average, fruits of Allahabad Safeda and Sardar took 165 and 155 days, respectively, from flowering to ripening under Bangalore condition (Fig. 3) (Selvaraj *et al.*, 1999). Mattiuz *et al.* (1997) working with 3 Paluma, Red Selection of Florida and Patillo in Brazil observed rapid fruit growth from 0–20 days, after which it slowed until day 80, when a new growth burst was observed. Fruit growth rate curves showed a quadratic pattern for all cultivars. From day 60 until day

100 (complete fruit formation) growth acceleration was detected, while fruit growth was low between day 20 and day 60. Red Selection of Florida and Paluma showed greatest mean daily growth rates (0.036 cm for fruit diameter and 0.042 cm for length), while Patillo grew only 0.027 cm/day in diameter and 0.033 cm/day in length.

The transitional colour development was observed only after period III (Rathore, 1976). The changes in skin colour during ripening depends on characteristics of cultivar; some cultivars show a change from green to yellow, whereas in others the colours remain green (Lim and Koo, 1990). The flesh colour, on the other hand, changes from white to either creamy white, yellowish pink, deep pink or salmon-red (Wilson, 1980). The transitional colour development usually occurs at the last phase of fruit maturity. The change in skin colour from deep green to yellowish green is attributed to the disappearance of chlorophyll and considered as a criteria in judging harvesting maturity (Ramkumar and Hoda, 1974). The flesh colour is mainly influenced by the presence of carotenoids, lycopene and β-carotene (Wilberg and Rodriguez-Amaya, 1995).

The total soluble solids of fruits continued to increase from anthesis to fruit ripening, irrespective of season (Srivastava and Srivastava, 1965; Dhillon *et al.*, 1987b), while total acids showed a decreasing trend with fluctuations from anthesis to ripening (Dhillon *et al.*, 1987b). The reducing, non-reducing and total sugar contents tended to follow the similar trend of TSS which might be ascribed to augmented translocation of photosynthates from leaves (Dhillon *et al.*, 1987b). The concentrations of starch, total phenolics and total pectin increased during early developmental stages but decreased while fruits approached ripening (Gangwar, 1972; Dhillon *et al.*, 1987b). The gradual decrease in starch and total phenolic contents as fruits approached ripening might be due to their hydrolysis in sugars, acids and other compounds (Gangwar, 1972). Ascorbic acid content increased with advancement of fruit maturity and ripening (Dhillon *et al.*, 1987b). Doraipandian and Muthukrishnan (1973) observed the presence of tartaric acid at flower bud stage and citric acid during the later stages of development of fruits in Red Fleshed guava. Selvaraj *et al.* (1999) studied fruit growth and development of Allahabad Safeda and Sardar guava fruits. They observed that fruit density, total acidity, skin chlorophyll, skin carotenoids, vitamin A, total pectins, crude protein, phosphorus, potassium, calcium, magnesium and sodium contents decreased; pulp pH, total tanins, dry-matter content and iron contents changed marginally, while TSS, vitamin C, sucrose, glucose and fructose contents increased during fruit maturation and ripening. The fruits of Allahabad Safeda had glucose : fructose ratio below 1 and those of Sardar above 1 during maturation and ripening. Citric acid was major acid together with malic, tartaric, pyruvic, succinic, fumaric, oxaloacetic, α-ketoglutaric and malonic acid formed 71–97% of the total non-volatile acids at various

ripening stages.

The biochemical and physical changes in Ganib, Pakistani, Shambati and Shendi were estimated by El-Buluk *et al.* (1995). They recorded that texture and protein contents decreased gradually and moisture and water-soluble pectin contents increased during fruit development in all cultivars. Alcohol-insoluble solids declined gradually during initial growing period followed by a rapid decline during later stages of development for all cultivars. Softeness and yellowness of fruit were associated with lower protein and alcohol insoluble solids contents, higher moisture and appreciable amounts of water-soluble pectin. The total sugar and ascorbic acid content increased significantly with the advancement of fruit maturity, while polyphenols was found to decrease with fruit growth and development in all the cultivars (El-Buluk *et al.*, 1997).

10

Harvesting and Yield

HARVESTING

Seedling guava trees come into bearing in 4–5 years, while vegetatively propagated trees bear quite early at the age of 2–3 years (Mitra and Bose, 1990). Fruits mature between 88 days (wild guava, *P. guinensis*) and 121 days (Chittidar) from fruit setting (Singh and Sharma, 1996). Harvesting is recommended at proper stage of maturity to ensure higher levels of total sugars and appreciable amounts of minerals (El-Buluk *et al.*, 1996).

Guava fruits should be picked immediately when they are mature as ripe fruits drop down and are likely to be damaged by birds (Mitra and Bose, 1990). During peak season, harvesting intervals cannot be more than 2–3 days. Otherwise, losses in overripe and insect- or disease-damaged fruits can become very severe. Dessert fruits are harvested at mature green stage, while fruits for processing should be picked at firm, yellow to half-ripe stage (Nakasone and Paull, 1998). Manual harvesting is a common practice in guava. Mechanical harvesting has been tried in some countries, but it is discouraged to avoid all possible damages to fruits and plants (Mitra and Bose, 1990). Paull and Goo (1983) stated that fruit detachment force is related to the stage of fruit development and fruit quality. It is an important consideration if mechanical harvesting is to be used. Mature green fruits require a detachment force of 75N or more, which declines to 10N in overripe fruits.

YIELD

Fruit yield is regulated by several factors such as age of tree, cultivar potential, plant density, weather conditions, and management practices (Mitra and Bose, 1990). In India, a seedling tree of 8–10 years old produces 400–500 fruits per year weighing 140–180 lb, while grafted or layered trees of the same age bear 1,000–1,200 fruits weighing 400–700 lb (Purseglove, 1974). In general, 500–600 fruits can be harvested from a healthy, fully bearing tree (Chandra and Chandra, 1997). At high altitude

in Meghalaya, yield ranged from 7.79 to 13.29 kg/tree and differed significantly among cultivars (Chandra and Govind, 1991). Fruit yields in 6th year were recorded to be 180, 135, 150 and 120 kg/tree in Allahabad Safeda, Apple Colour, Lucknow 49 and Allahabad Surkha (Nand *et al.*, 1991). Mitra (1983) stated that all cultivars gave higher yield in rainy season than the winter season. Guava hybrids Hisar Safeda and Hisar Surkha produced 114 and 94 kg fruits/tree/year, respectively (Daulta *et al.*, 1998). Kundu and Mitra (1994b) in an evaluation trial with 12 guava cultivars recorded an yield variation of 190–121 kg in rainy season and 41–162 kg/ha in winter season in laterite tract of West Bengal (Table 10).

Table 10. Yield of guava cultivars in 2 seasons

Cultivar	Yield (kg/ha)	
	Rainy season	Winter season
Allahabad Safeda	9,920	1,490
Allahabad UP	7,540	860
Apple Colour	10,480	1,350
Banarasi	11,290	1,090
Baruipur	11,430	1,130
Behat Coconut	9,620	860
Chittidar	12,120	1,170
Harijha	10,300	1,330
Karela	9,420	1,040
L-49 (Sardar)	13,490	1,620
Seedless	1,900	410
Supreme	7,380	760
SEm ±	370	100
CD (5%)	1,020	280

*Kundu and Mitra (1994b)

In Australia, an yield of 52.3 tonnes/ha was obtained at a plant density of 805 trees/ha (Chapman *et al.*, 1981). The average production in Hawaii is about 26.9 tonnes/ha, while in Taiwan an yield of up to 120 kg/tree could be obtained with 600–800 trees/ha by using the open centre flat pruning (Nakasone and Paull, 1998).

11

Composition and Utilization

Guava is an excellent source of ascorbic acid, dietary fibre, pectin and minerals. The composition of ripe guava fruits is given in Table 11. The composition of guava fruits vary widely with cultivars, stage of maturity and season (Rathore, 1976; Ojha *et al.*, 1987; Das *et al.*, 1995; Kundu *et al.*, 1995; Ghosh and Chattopadhyay, 1996). Variation in total soluble solids (TSS) from 8.2 to 10.5 ^{0}Brix has been reported by Mitra (1983) and Kundu *et al.* (1995). The predominant sugars are fructose (59%), glucose (36%) and sucrose (5%) (Chan and Kwok, 1975). Fructose is the principal sugar in green ripe fruits, while fully ripe fruits contain higher amount of sucrose. Its fruits also contain considerable amount of vitamin A, thiamine, riboflavin and niacin (Wenkam, 1990). The ascorbic acid is mainly found in skin and a slightly lower concentration is found in flesh (Nakasone and Paull, 1998). The ascorbic acid content varies with cultivar, season, location and stage of maturity (Dhar and Sachan, 1980; Singh, 1988; Das *et al.*, 1995; Ghosh and Chattopadhyay, 1996). Pink-fleshed cultivars are usually low in ascorbic acid content than white-fleshed ones (Mitra *et al.*, 1984b). Winter season fruits are superior in quality to rainy season crop (Rathore, 1976; Ojha *et al.*, 1987; Ghosh and Chattopadhyay, 1996), which might be an effect of low temperature (Rathore, 1976).

The mean nutrient element (mg/g) concentration in fruits were recorded (N=8.2, P=0.72, K=8.98, Ca=2.02, Mg=6.16, S=0.17, Fe=0.03, Mn=0.01, Zn=0.02 and Cu=0.02). The nutrient contents of different fruit parts are presented in Table 12 (Varalakshmi and Bhargava, 1998). The fruits are high in pectin (Nakasone and Paull, 1998) ranging between 0.5 and 1.8% (Adsule and Kadam, 1995). Variation in pectin content in cultivars has been reported and there was no specific trend in pectin content between pink and white-fleshed cultivars or hybrids (Baramanray *et al.*, 1995). Among organic acids, citric and malic acids are predominant, though glycolic, tartaric and lactic acids are also present (Adsule and Kadam, 1995). The characteristic flavour of fruits is due to hydrocarbon, alcohol and carbonyl compounds. Several volatile aromatic compounds have been found in guava during ripening (*see* Chapter 14).

Table 11. Proximate composition of guava fruits*

Constituent		Amounts
Moisture	(g/100 g pulp)	77.9–86.9
Dry-matter content		12.3–26.3
Ash		0.51–1.02
Crude fat		0.10–0.70
Crude protein		0.82–1.45
Crude fibre		2.0–7.2
Sugar		
Reducing		2.4–5.2
Non-reducing		2.5–3.8
Total		4.9–10.1
Acidity	(mg/100 g pulp)	0.22–0.39
Ascorbic acid		75.2–234.3
Thiamine		0.03–0.07
Riboflavin		0.02–0.04
Niacin		0.20–2.32
Nitrogen		8.20
Phosphorus		0.72
Potassium		8.98
Calcium		2.02
Magnesium		6.16
Sodium		0.17
Iron		0.03
Manganese		0.01
Copper		0.02
Zinc		0.02

*Wilson (1980), Das *et al.* (1995), Ghosh and Chattopadhyay (1996), Varalakshmi and Bhargava (1998)

Table 12. Nutrient element composition of epicarp, mesocarp and seeds of guava fruits (per cent fresh weight)*

Nutrient		Epicarp	Mesocarp	Seed
N	per cent	0.078	0.029	0.88
P		0.0034	0.0017	0.144
K		0.149	0.065	0.158
Ca		0.038	0.0042	0.059
Mg		0.104	0.0045	0.097
S		0.002	0.0002	0.017
Fe	ppm	4.04	1.59	22.82
Mn		1.24	0.27	4.31
Cu		1.71	0.98	20.12
Zn		1.24	0.65	19.58

*Varalakshmi and Bhargava (1998)

Guava fruits are consumed either fresh or processed. Good quality salad can be prepared from the shell of ripe fruits. Guava jelly is very

popular for its attractive purplish-red colour, pleasant taste and aroma. The common sour wild guava is best for jelly preparation. Puree made from guava EEA 18-40 is best in flavour, colour and aroma (Pinera *et al.*, 1997). The ascorbic acid content and flavour are almost maintained in puree, but there is a significant, though not objectionable change in colour (Nakasone and Paull, 1998). Loss of pink puree colour in storage is more rapid at 38°C than at ambient temperature (Chan and Cavaletto, 1982). The puree can be used in juice, cakes, puddings, sauces, ice-cream, jam and jelly (Nakasone and Paull, 1998).

Its fruits can be preserved by canning as halves or quarters, with or without seed core (shells). Siddapaa (1982) stated that guava Allahabad Seedless White is more suitable for canning as halves. High quality nectar can be prepared from guava and hybrids are superior to common cultivars in this respect (Baramanray *et al.*, 1995). Guavas are also dehydrated and powdered. Two types of wine, viz. guava juice wine and guava pulp wine can be manufactured from ripe fruits (Bardiya *et al.*, 1974). Good quality ready-to-serve beverage can also be made from guava (Pandey and Singh, 1999). The seeds contain 5–13% oil which is rich in essential fatty acid and can be used in salad dressing (Adsule and Kadam, 1995). Leaves of guava have medicinal properties. They are used for curing diarrhoea, and also for dyeing and tanning.

12

Packing, Transportation and Marketing

GUAVA fruits are harvested into plastic buckets or packing bags. They are packed in larger bins. Fruits should not be packed in hessian bag as it may cause considerable damage during transportation. Positioning of guava fruits in natural posture with pedicel end vertically upward may result in better keeping quality as compared with fruits kept in reverse, or horizontal position. Guava fruits have very short shelf-life making it difficult for distant marketing. For long distance transportation, use of proper packaging and cushioning material has been reported to enhance shelf-life of fruits (Sharma *et al.*, 1974). Fruits packed in polythene bags had minimum physiological loss in weight on all periods of storage, whereas fruits wrapped in newspaper showed maximum physiological loss in weight. The TSS, acidity and ascorbic acid contents of fruits were not affected by any of the cushioning materials (Kumar *et al.*, 1998). Refrigerated transport can reduce the spoilage of fruits.

13

Pests and Diseases

Guava is attacked by a number of insect pests. A few important insect pests are:

PESTS

Oriental fruit fly (*Dacus dorsalis*; *D. diversus*; *D. zonatus*)

The adults lay eggs under the skin of fruits during monsoon. On hatching, maggots feed on pulp resulting into brown patches (Arya, 1993) and affected fruits in most cases drop down (Mitra and Bose, 1990).

The affected fruits should be destroyed. Periodic sprays with malathion (0.1%) or demicron (0.1%) minimize the pest incidence. Poison baits are also used to kill the adult fly. Plastic bucket tray baited with methyl eugenol (4 ml/trap on a cotton wick) and placed on guava trees 5 feet above the ground at a density of 1/acre caught significant number of male fruit flies (Marwat *et al.,* 1992; Stark and Vargas, 1992). The colour of trap (white and yellow) enhanced the trap efficiency which might be due to intensity of reflected light (Stark and Vargas, 1992).

Bark-eating caterpillar (*Inderbela quadrinotata*; *I. tetraonis*)

This is a common insect of tropical region. It is known to attack a number of fruit trees. The larvae on hatching feed on bark and bore into woods. The affected branches sometimes die due to disturbance in sap movements. The adults are nocturnal in habit. There may be about 15–30 larvae on a single tree (Arya, 1993).

Injection of 5 ml of kerosene oil or CS_2 into hole and sealing it with cotton wool or mud gives good control (Arya, 1993). The dead branches can be made to sprout by cutting them along with some healthy tissue during rainy season. Seedless and Apple cultivars are more susceptible than Allahabad Safeda, Strawberry and Cattley guava.

Mealy bug (*Drosicha mangiferae*)

Guava is attacked by mango mealy bug (*Drosicha mangiferae*) and citrus mealy bug (*Planococcus citri*). The mealy bugs suck sap from young leaves, tender twigs and flowers (Mitra and Bose, 1990). It seems to be difficult to control the pest once it has climbed up. Dalaya *et al.* (1983) reported that banding the tree trunk with 30 cm wide, 400-gauge polythene combined with grease on 5 cm area on its lower end and plugging the space between trunk and band effectively controlled the pest. Spraying of insecticides, viz. chlorpyrifos (0.08%), acephate (0.08%), cypermethrin (0.02%), methyl demeton (0.08%), monocrotophos (0.08%), quinalphos (0.08%), fenvalerate (0.02%), carbaryl (0.2%), phosphamidon (0.08%) and phenthoate (0.08%) was effective in controlling larvae of mango mealy bug infesting guavas (Ghule and Dhumal, 1992). Hussain *et al.* (1996) recommended spraying of neem oil and pongamia oil (4%) to control citrus mealy bug on guava.

Scale insect (*Chloropulvinaria psidii*)

It is one of the serious pests of southern and western India. The green sticky insects are found on leaves, shoots and fruits. The affected branches should be pruned and destroyed. Spraying of systemic insecticides is effective to control the pest. Two applications of fish oil, rosin soap, 500 g in 36 litres of water, or crude oil emulsion (7.8 kg in 450 litres of water) minimized the pest incidence (Mitra and Bose, 1990).

Stem-borer (*Aristobia testudo*)

Recently litchi stem-borer has been reported to cause havoc to guava growers of North-eastern region of India. Its grubs feed voraciously within stem, making tunnels/galleries up to 1.5–2.0 m long, killing the trees within a year. Straw-coloured pellets (fecal matter) are seen accumulated at the base of tree indicating infestation of the borer. Both young and adult plants suffer from its attack (Shylesha *et al.*, 1997).

The adults of trunk-borer are conspicuous beetles and can be collected and killed easily during June–September. Injection of 5 ml of dichlorovos (0.1%) or monocrotophos (0.2%) per hole gives effective control. Young plants should be treated with carbofuran granules @ 1 kg a.i./ha in root zone (Shylesha *et al.*, 1997). The quarantine measures should be adopted in the movement of guava saplings from NEH region to other parts of India.

Thrips (*Rhipiphorothrips cruentatus*)

Thrips cause damage to fruits during March, August and September. They can be very troublesome, causing silvering of leaves and scarification

of fruits. The affected fruits do not develop and become mummified (Nakasone and Paull, 1998). Guava Allahabad Safeda, Ruby × Supreme Hybrid, and Lucknow 49 (Sardar) have high degree of resistance to thrips. The degree of resistance increases with foliar sprays of N and K (Foss, 1980).

Recent report indicates that, pomegranate butterfly (*Virachola isocrates*) also causes damage by boring into immature guava fruits during August–September (Biswas *et al.*, 1995). Spraying of carbaryl (0.2%) at 10–12 days interval can reduce pest population. Guava Sindh was found to be most resistant (Yadav and Pandey, 1994), while Swarupathi was least susceptible and Kazipiara highly susceptible to this pest (Biswas *et al.*, 1995).

Nematodes (*Meloidogyne incognita*; *M. mayaguensis*)

Severe attack of root-knot nematode has been reported from Nelspruit, South Africa. The growth of tree is checked with poor vigour and unthrifty appearance. As a result, yield decreases and trees decline. Application of cadusafos (100 g/kg), neaticide @ 10 g/m^2 provided best protection against root-knot nematode (Willers, 1997a and b). In Colombia, *Meloidogyne* sp. was found as the main nemotode affecting guava but *Helicotylenchus* spp., *Pratylenchus* spp., *Rotylenchulus* spp., *Hoplolaimus* spp., *Tylenchorhynchus* spp. and *Xiphinema* spp. were also present (Mosquera *et al.*, 1997). Using plant extracts of *Tagetes* spp. showed an average of 55% control.

DISEASES

Guava wilt

As a fungal disease it is most prevalent in Uttar Pradesh, West Bengal, Bihar, Rajasthan and Madhya Pradesh. It has been estimted that in badly infected districts of Uttar Pradesh, 5–20% trees are killed annually (Tandon, 1967). The actual causal organism of wilt is yet to be confirmed. The pathogens, viz. *Fusarium oxysporium* f. sp. *psidii*, *F. solani*, *Macrophomina phaseoli*, *Rhizoctonia bataticola* and *Cephalosporium* sp. may incite the disease (Misra, 1996).

It is characterized by splitting of stem bark, yellowing of leaves, drying of leaves and twigs from the tip followed by complete wilting of tree within 10 to 15 days (Mitra and Bose, 1990). The symtoms can be seen as slow and suddenly. The pathogen *M. pahseolina* (dominated in alkaline soil) is associated with slow wilt, while *F. oxysporium* f. sp. *psidii* (dominated in acid soil) is associated with sudden wilt (Chakraborty and Singh, 1989). The disease seems to occur more severely in alkaline soils. The symptoms produced are not influenced by different pathogens

involved. Histopathological studies revealed the presence of hyphae in xylem vessels of infected roots (Pandey and Dwivedi, 1985).

Pruning and buring of affected twigs followed by spraying of Bavistin (0.1%) at fortnightly interval at early stage of infection can minimize its infection (Mitra and Bose, 1990; Arya, 1993). The wilted plants should be uprooted and pits should be disinfected by burning dry leaves (Arya,1993). Soil solarization using a 30 mm transparent polyethylene sheet controlled *F. oxysporium* f. sp. *psidii*, *F. solani* and *R. solani*. Banarasi, Dholka, Sindh, Nasik white, Supreme and Lucknow 49 have been reported to be resistant to this disease (Arya, 1993). A local variety of Taiwan, Peipa, has been reported to be resistant and *P. friedrichsthalianum* has been recommended as a promising rootstock (Leu and Kao, 1979).

Anthracnose

The *Pestalotiopsis psidii*, *Colletotrichum gloeosporioides* (*Glomerella cingulata*) and *Botryodiplodia theobromae* were isolated from infected fruits and pathogenicity was confirmed (Hossain and Meah, 1992). It has been reported to be a serious disease in western districts and Uttaranchal (Mitra and Bose, 1990). The pathogen, *G. psidii*, causes appearance of many small, shallow, water-soaked lesions on fruit surface, which later on coalesce and under humid conditions they develop salmon-coloured spore masses at the centre of lesion. It causes dark brown spots on leaves and fruits, which spread very fast on leaves covering the entire leaf surface. Affected fruits rot in storage. Spraying of Bordeaux mixture (3 : 3 : 50) + copper oxychloride and cuprous oxide at weekly intervals effectively controlled the disease (Tandon and Singh, 1969). Dipping of fruits in 50 ppm Aratan for 2 minutes either before or after inoculation gave good protection against *C. gloeosporioides* (Khanna and Chandra, 1976). Gupta and Chatrath (1973) reported that gamma radiation could be used for post-harvest decay of guava caused by *C. gloeosporioides*. Application of Topsin M (thiophenate-methyl) resul-ted into most significant reduction in fruit infection and disease severity followed by Rovral FLO (iprodione), Rovral WP and Dithane M-45 compared with untreated control (Hossain and Meah, 1992).

Styler-end rot

This disease is caused by *Phomopsis psidii* and *P. destructum* (Arya, 1993). The occurrence of this disease was first reported from Lucknow. Circular, water-soaked lesions occur at styler-end; later on pycnidia of white or light brown colour appear on infected region. Variation in varietal susceptibility to this disease has been reported. The percentage of rot was 85% in Apple guava compared with cent per cent in Allahabad

Safeda 15 days after incubation.

Leaf extracts of *Azadirachta*, *Eucalyptas*, *Ocimum* and *Strychnos* and treetment with Bavistin, Difolatan and Calyxin (1000 ppm) gave satisfactory control.

Stem canker

It is caused by *Physalospora psidii*. The bark of stem of affected plants crack and twigs wilt due to collapse of stem tissues. Brown spots appear on calyx end of fruits. The infected shoots should be prunned and cut surface should be covered with copper fungicides (Mitra and Bose, 1990).

Phytophthora fruit rot

This disease is caused by *Phytophthora nicotianae* var. parasitica. It is a major disease in Haryana, Punjab, Rajasthan and Karnataka during rainy season. The disease causes considerable losses (Sohi and Sridhar, 1971). White cottony mycelial growth occurs at styler-end of fruits with initiation of ripening process and covers entire fruit within 3–4 days. The disease may also occur on unripe fruits and causes considerable damage of fruits in storage.

Metalaxyl (Ridomil 25 WP) and copper oxychloride (Blitox) gave 100% control to pathogens (Seema *et al.*, 1995).

Grey blight and fruit canker

The *Pestalotia psidii*, *Pestalotiopsis clavispora* and *P. palmarum* are probably causal organisms. Dark, reddish brown corky lesions or cankerous spots with raised margins and depressed centres appear on fruits. Pathological studies indicated that *P. psidii* hydrolyzed the entire sucrose content of fruits within 6 days. The optimum temperature for growth and sporulation was reported as 25–30°C (Tsay, 1991).

Storing of fruits at low temperature and dry atmosphere can prevent its incidence (Kaushik *et al.* 1972). Leaf extracts of neem and *tulsi* controlled 100 and 90%, respectively. Carbendazim, flusilazole and imazalil were most effective in inhibiting the mycelial growth and spore germination (Tsay, 1991).

Aspergillus rot

The *Aspergillus niger*, *A. nanus*, *A. parasiticus*, *A. phoenicis*, *A. flavus*, *A. flavips* and *A. awamori* are reported to cause this disease. High humidity in combination with high temperature (30–35°C) favours the development of disease. Small, water-soaked, brownish lesions appear on

fruit surface, which gets depressed at the centre with age and increases in size. Later on black mouldy growth appears on surface of infected fruits. The whole fruit becomes black within 10–12 days (Arya, 1993).

Pre-inoculation treatment with 1250 ppm Bavistin and Saprol for 2 minutes has been recommended to control this disease.

Seedling blight

This is caused by *Rhizoctonia* sp. Seedlings of less than 4 months age are very susceptible to this disease. The disease is prevalent in wet weather. Small, circular to irregular brownish spots appear on leaves, which spread rapidly under humid conditions, covering the entire lamina and petiole. The affected leaves drop down and finally the plant dies.

The seedlings can be prevented from attack by application of Captan (0.2%) or Ferbam (0.3%).

Mucor rot

Mucor fruit rot (*Mucor hiemalis*) first appears as a water-soaked area and later becomes covered with yellowish, fuzzy mycelia and fruiting bodies (Nakasone and Paull, 1998).

The fallen fruits should be collected and destroyed. Cultivars with low acid and high sugar content are more tolerant to this disease than acid types (Nakasone and Paull, 1998).

14

Ripening and Storage

RIPENING

GUAVA is a climacteric fruit, showing a typical increase in respiration and ethylene production during ripening (Brown and Wills, 1983; Ali and Lazan, 1997; Selvaraj *et al.* 1998). Selvaraj *et al.* (1998) observed climacteric peak in respiration at yellow hard stage. The ethylene content increases from green to colour-turning stage and declines thereafter in ripe stage. The climacteric peak in respiration was found preceded by maximum ethylene evolution (Selvaraj *et al.*, 1998). In 'Kampuchea' activities of enzymes polygalacturonase, pectinesterase, b-galactosidase and cellulase increase with ripening (Chin *et al.*, 1994), however, in Allahabad Safeda and Sardar guavas, cellulase and β-galactosidase activity decrease during ripening and that of PE and PG decrease from green-to-peel colour-turning and or yellow hard stage and increased in ripe fruits (Selvaraj *et al.*, 1998). Acid phosphatase activity decreases during climacteric period.

The sucrose phosphate synthase, responsible for sucrose synthesis from hexose phosphates, increases its activity from green-to-green mature stage and decreases in later ripening stage. The sucrose synthase activity in sucrose synthesis direction increases from green-to-geeen mature stage in Sardar guava and green-to-yellow hard stage in Allahabad Safeda which decreases in later ripening stages. Activity of another sucrose hydrolysing enzyme, acid invertase increases in Allahabad Safeda and decreases in Sardar with ripening (Selvaraj *et al.*, 1998). Polyphenoloxidase, the enzyme responsible for oxidation of polyphenols, increases in activity during ripening (Mowlah and Itoo, 1982), and this may be the cause of reduction in astringency in ripe guava (Ali and Lazan, 1997).

Idstein and Schreir (1985) identified about 154 different volatile compounds in guava fruits, which include carbonyls, esters, alcohols, hydrocarbons, acids, sulphur-containing compounds and other volatiles. Cinnamyl acetate, one of the major volatile compounds present in guava, has most guava-like aroma. Vernin *et al.* (1998) analysed volatile aroma

compounds from red (*P. cattleianum*) and yellow (*P. cattleianum* var. *lucidum*) fruits (collected from Reunion). They identified 31 hydrocarbons, 9 acetals, ethers and oxides, 13 aldehydes, 13 ketones, 30 esters, 48 alcohols, 2 acids, 2 sulphur-containing compounds and 4 phenol derivatives, menthofuran and coumarin.The aroma of red fruits was thought to consist of fruity notes due to ethyl esters (C_4–C_{16}), tiglates, cinnamates, floral notes attributed mainly to terpenic alcohols, 2-phenylethyl alcohol, b-ionone and 1-phenylpropane-1,2-dione; spicy notes due to cinnamaldehyde, eugenol and methyl isoeugenols; burnt notes due to furfural and 2-acetylfuran; herbaceous, slightly spicy-like odour due to 2-tridecanone; and sweet and blasmic notes due to benzylbenzoate.

STORAGE

Post-harvest life of guava is about 2–3 weeks at 5–10°C (Yahia, 1997). Fruits stored treated with aureofungin and ethylene chlorohydrin plus calcium carbonate could be stored at room temperature for 5 days without spoilage and up to 7 days with only 25% spoilage (Mitra and Bose, 1990). Packing of fruits in polythene bags extended the storage life for up to 14 days at 8–10°C with 100% marketability (Nakasone and Paull, 1998).

Balakrishnan *et al.* (1994) observed that fruits with higher specific gravity could be stored for longer duration than fruits with low specific gravity. High incidence of fruit browning after harvesting is generally associated with low TSS, ascorbic acid and total acidity contents (Nawar and Ezz, 1994).

Several pre- and post-harvest treatments have been found to be effective in extending the shelf life of fruits. Pre-harvest spraying of calcium nitrate (1.5%) minimizes physiological weight loss during storage and maintain the eating quality and marketability of fruits for more than 8 days (Chandra *et al.*, 1994). Post-harvest dipping of fruits in $CaCl_2$ (3%) and GA_3 (100 ppm) reduces skin browning and polyphenol oxidase (catechol oxidase) activity (Nawar and Ezz, 1994). Wrapping of fruits in newspaper or used type papers is beneficial in prolonging shelf-life of fruits by around 3 days (Siddiqui and Gupta, 1997).

Coating of mature-green fruits with cellulose- or caranuba-based emulsions delayed ripening and slows softening, but causes less colouring and more surface blackening (McGuire and Hallman, 1995). The fruits of Allahabad Safeda stored at ambient temperature with modified atmosphere coating in wax solution is found inferior to modified atmosphere packaging in polyethylene film (Singh *et al.*, 1993). Fruits of Kumagai wrapped in low-density polyethylene bags and sotred at 8°C for 3 weeks showed less dehydration, contained less acid and soluble solids, low-chilling injury intensity and decreased severity of post-harvest diseases (Gaspar *et al.*,

Table 13. Recommended storage conditions for guava fruits

Temperature (°C)	Relative humidity (%)	Duration (weeks)	References
8.3–10	85–90	2–5	Pantastico (1975)
10	90	3	Mercantilia (1989)
5–10	90	2–3	Hardenburg *et al.* (1990) Snowdon (1990)
10	85–90	2–3	SeaLand (1991)
9–10	85–90	3	Singh (1995)

1997). Removal of ethylene may extend the storage life of guava stored at 20°C (Broughton and Leong, 1979), although storage under 10% CO_2 delays ripening, it causes physiological injuries to fruits.

The storage temperature and humidity recommended by various workers are given in Table 13.

15

Economics of Production

The study of economics of guava requires the input-output coefficients over a period of time. The initial expenses right from land preparation and planting till harvesting is considered as the establishment cost. Singh *et al.* (1993) worked the cost of cultivation for Allahabad Safeda and Sardar guavas in Uttar Pradesh. The details of first 2-years (pre-bearing) cost of cultivation are as follows (Table 14). The recurring operational cost for maintaining an orchard from third year onwards showed an expenditure of between Rs 4,090 and 5,204/ha (Table 15). The trees usually starts production from the end of second year or at the beginning of third year. The maximum benifit : cost ratio of 6.09 was estimated when its trees were 5–10 years old which gradually decrease to 4.40 when the tree age was more than 16 years (Table 16). In first 2 years after planting the interespace between plants may be suitably used by growing intercrops, which may supplement the income of growers in pre-bearing stage.

Table 14. Cost of cultivation during pre-bearing stage

Item	Cost (Rs/ha)	
	First year	Second year
	Labour cost	
Field preparation and pit digging	860.00	204.50
Manures and fertilizers application, basin formation and irrigation	665.50	870.00
Sub-total	1,525.50	1,074.50
Saplings	1,200.00	200.00
Manures	847.50	680.50
Fertilizers	460.00	1000.00
Plant protection	–	100.00
Electricity charges for irrigation	610.00	610.00
Miscellaneous	390.00	213.50
Sub-total	3,507.50	2,804.00
Total cost	5,032.00	3,878.50

*Singh *et al.* (1993)

Table 15. Cost of maintaining a bearing orchard*

Age of crop (year)	Cost items					Total cost (Rs/ha)
	Labour**	Manures	Fertili-zers	Plant pro-tection	Irrigation	
3	1,500	700	1,290	175	425	4,090
4	1,275	600	1,720	195	400	4,190
5–10	2,080	724	2,150	280	400	5,634
11–15	1,680	624	2,150	350	400	5,204
16 onwards	1,105	640	2,150	300	250	4,445

* Singh *et al.* (1993)
** Includes cost of pruning and harvesting

Table 16. Returns from orchard*

Age of tree	Yield level (tonnes/ha)	Gross Return** (Rs)	Net Return (Rs)	Benefit : cost ratio
3	8	16,000	11,910	2.90
4	10	20,000	15,810	3.77
3–10	20	40,000	34,366	6.09
11–15	18	36,000	30,796	5.91
16th and above	12	24,000	19,555	4.40

** @ Rs 2.00/kg of guava fruits
* Singh *et al.* (1993)

The economic potentiality and viability of guava cultivation under scientific management at Raichur, Karnataka, was examined by Hugar *et al.* (1991). They estimated the establishment cost of guava orahcards as Rs 6,448/ha. Out of which, opportunity cost of land (46.45%) formed the major component followed by expences on planting material (12.54%) and irrigation (8.67%). Therefore, a farmer owing the land would have to incur only 53.55% of the above mentioned establishment cost. The maintenance cost from third year onwards, varied from Rs 2,855 to 7,034/ha. The net return estimated 5 years after planting was Rs 2,447/ha which increased between Rs 20,000 and 30,974/ha during seventh to tenth years. The benifit : cost ratio was estimated as 3.88.

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INDEX

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